ORNAMENTAL AND TURF PEST CONTROL

UDAF

Utah Department of Agriculture and Food

PLANT INDUSTRY

PESTICIDE APPLICATION
AND SAFETY TRAINING
STUDY GUIDE

UTAH DEPARTMENT OF AGRICULTURE AND FOOD
DIVISION OF PLANT INDUSTRY

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INTRODUCTION TO PLANT PROBLEMS

The educational material in this study guide is practical information to prepare you to meet the written test requirements. It doesn't include all the things you need to know about this pest-control subject or your pest-control profession. It will, however, help you prepare for your test.

Contributors include the Utah Department of Agriculture and Utah State University Extension Service. This study guide is based on a similar one published by the Colorado Department of Agriculture. Materials for that guide were prepared by Colorado State University Extension Service. Other contributors include: University Cooperative Extension Service personnel of California, Kansas, New York, Oregon, Pacific Northwest, Pennsylvania, and Wyoming. Other contributors were the U.S. Department of Agriculture -- Forest Service, the United States Environmental Protection Agency (Region VIII), the Department of Interior -- Bureau of Reclamation, and Metro Pest Management.

The information and recommendations contained in this study guide are based on data believed to be correct. However, no endorsement, guarantee or warranty of any kind, expressed or implied, is made with respect to the information contained herein.

Other topics that may be covered in your examinations include First Aid, Personal Protective Equipment (PPE), Protecting the Environment, Pesticide Movement, Groundwater, Endangered Species, Application Methods and Equipment, Equipment Calibration, Insecticide Use, Application, Area Measurements, and Weights and Measures. Information on these topics can be found in the following books:

1. **National Pesticide Applicator Certification Core Manual,** Published by the National Association of State Departments of Agriculture Research Foundation.

2. **The Workers Protection Standard for Agricultural Pesticides – How to Comply: What Employers Need to Know.** U.S. EPA, Revised September 2005, Publication EPA/735-B-05-002.

These books can be obtained from the Utah Department of Agriculture or Utah State University Extension Service. Please contact your local Utah Department of Agriculture Compliance Specialist or Utah State University extension agent.

INTEGRATED PEST MANAGEMENT

Integrated Pest Management recognizes a variety of pest control techniques. IPM considers social, environmental and monetary costs. Interest in IPM methods is often based on a desire to limit pesticides. However, pesticides are frequently used IPM techniques. Pests can develop damaging levels in given areas year after year. Early treatment controls pests before they cause extensive damage. Before treating pests, wait until an economic or aesthetic threshold is reached. These thresholds are used to determine if controls are needed and when to use them. The **Economic Threshold** is the point when damage justifies the control costs. When pests cause damage, decide whether to initiate control measures or accept some loss. The **Aesthetic Threshold** is the point when pests cause unacceptable visible damage to ornamental plants.

Most landscape IPM programs:

- Stress plant health to reduce pest losses. Healthy, vigorous plants tolerate or avoid pests. Never use pesticides to compensate for cultural problems.
- Use sanitation, cultural controls and pesticides coordinated with natural plant healing or biological controls.
- Monitor pest problems to make sound management decisions. This detects pest population increases or declines allowing treatments to target needed areas. Monitoring gives proper pest control timing.
- Use IPM techniques to manage pests at acceptable levels rather than eliminate them. Pests are tolerable if injury levels remains below where control costs exceed threatened damage. In ornamentals, the pest damage level is often obscured by aesthetic considerations.
- Help clients recognize that plant health requirements are separate from artificial aesthetic requirements. Injury levels are often so low there is no reason to control pests.
- Give priority to reducing environmental injury. Environmental management costs are important considerations.
- Avoid IPM incompatible "insurance" applications. Use preventive applications only if pest injury is predictable and where options do not exist after infestations occur (for example, borers or bark beetles on high-risk trees).

Pest Control Solutions

Plant pest infestations are similar to human illness. Successful treatment follows a sequence of controls.
Examine the site and organisms and check the normal or healthy plant condition. If the plant shows signs of poor health or appears abnormal, look for possible causes.
Identify and assess potential problems, their causes and severity. All organisms on plants are not pests. Some are incidental, others are beneficial. Some pests cause little damage in the beginning, but can become serious problems.
Determine a control prescription based on examination identification and assessment. Choose preventive, curative, or no action. Take no action if infestations are not serious, when curative action causes more harm than the infestation, or curative timing is not appropriate. Take no action until pests are vulnerable.
Apply pesticides if they are the best control. Choose the best chemical and application method. USU Extension Agents, distributors and labels have additional control information. Pest problems are not solved by merely knowing problems and what to do about them. Apply the prescription correctly. Pesticide applications are the most common pest control intervention.
When selecting and using a pesticide consider:

- Is this pesticide safe where and how is it used?
- Is the pesticide likely to harm plants being protected?
- Will the pesticide kill beneficial insects or animals?
- Are pesticide label directions easily understood?
- When is the best time to use this pesticide?
- How and to what is the pesticide applied?
- Is the pesticide registered with the EPA for this use?

Evaluate the results Did the prescription work? Base the evaluation on considerations listed above.

IPM Controls

IPM uses non-chemical controls when possible to minimize pests. These include:
Legal Controls: These keep pests out through legal quarantines, careful plant selection and unwanted introductions. Eradication programs are usually conducted by government agencies to totally eliminate pathogens from a host area. This is difficult if pests are common in a large area.

Resistance: Resistant plants are developed through breeding, selection and genetic engineering. Total immunity is rare, but resistant varieties allow growth in spite of pests.
For example, select mildew resistant roses or zinnias
Sanitation: To prevent pests, remove them, their food, shelter, or unhealthy tissue. For example, remove marigolds infected with white mold. Sort, screen, handpick, rogue and destroy affected seeds, nursery plants, and propagation stock.
Remove weeds or alternate plants that host viruses or insect pests. Treat tools with disinfectant to remove pathogenic organisms. For example, sterilize pruners after cutting branches affected with fire blight.
Mechanical or physical control: Use insect screens, machines and other methods to control pests or alter their environment. Avoid bruising plants during handling to prevent injuries and reduce infections.
Cultural Controls: Healthy plants tolerate injuries better than stressed plants. Plant the right plant in the right location, alter the environment, modify plant conditions, or influence pest behavior to suppress or prevent infestations. This makes pests less likely to survive, grow or reproduce. Vary planting or harvest times and use good irrigation and fertilizing practices. Space plants and avoid excessive watering to suppress crown and stem rot. Use drip or surface irrigation to avoid spreading diseases. Plant cool season crops early to avoid root rot in warm soils.
Natural Controls: Pathogenic or non-pathogenic controls eliminate most pest problems. In a balanced ecosystem, natural enemies control pests. Pest outbreaks occur when natural controls fail. Typical nonpathogenic controls are high winds, rain, extreme heat, or freezing temperatures. Cold, wet weather helps control insects. Natural pest enemies are effective in most ecosystems. Predators, parasites and diseases are important pest controls. Environmental factors that diminish their effectiveness include dust, unfavorable weather, biological competitors, drift of pesticides from adjoining areas or pesticide use on a crop. Host plant defenses are important controls. Insects can be pushed out of feeding wounds in trunks by gums or resins. Leaves and needles can be toxic so pests will not eat them. Leaf coatings prevent disease infections.
Biological Controls: These are parasites, predators, or pathogenic organisms that feed on or damage pests. They are introduced by people rather than occurring naturally. Biological control advantages include permanence, safety and economy. Once established, they are relatively safe without hazardous toxicity or environmental pollution. Biological controls are not suitable for all pests. Parasites or predators need time to develop a large enough population to control pests. This can take too long to save an endangered crop. It is challenge to find parasites or predators to introduce.
Eliminating secondary parasites of beneficial parasites, protecting beneficials from insecticides and determining whether continuous releases are needed are other challenges. Introducing biological controls in small isolated landscapes is usually not effective.

Pesticides: Chemicals control or destroy pests or prevent them from causing damage. Pesticides can attract or repel pests. Plant growth regulators, desiccants, and defoliants are also classified as pesticides although they do not control pathogenic organisms. Pesticides are only one control method.

PESTICIDE BASICS

PESTICIDE NAMES

The word “pesticide” can be split into “pest,” “an unwanted organism,” and “cide” meaning “to kill.” The word means “to kill the pest.” Unfortunately, it is erroneously used to describe only insecticides or other products. Saying “pesticides and herbicides” is redundant and incorrect as is saying “pesticides and insecticides.” Pesticide is an overall term, while insecticide is more specific because it controls insects, a fungicide controls fungi and a rodenticide controls rodents. Other common but improper terminology is to call a product a “weedkiller” instead of an “herbicide.” Since herbicides kill most plants and not just weeds, it is the preferred term. Likewise, the term “bug killer” refers to products that control true bugs or members of the insect order, Hemiptera. A true bug killer would not affect grasshoppers, flies, mosquitoes or beetles or any other insects that are not true bugs.

PESTICIDE LIMITATIONS

All control measures upset the natural balance in some way. Pesticides control pests but have many side effects.
Drawbacks include the following:
• Development of pest strains resistant to pesticides.

- Temporary controls requiring repeated treatments.
- Pesticide residues in the harvested crop.
- Outbreaks of secondary pests, resulting from the destruction of natural enemies.
- Undesirable damage to non-target organisms such as beneficial parasites and predators, fish, birds or other wildlife, pollinators, man, domestic animals and other plants.
- Direct hazards in applying pesticides.
- Specific hazards, formulations and equipment needs that are covered in the study guide safety section.

PESTICIDE MIXTURES

Pesticide mixtures are designed to do two jobs with one application. Mixtures of fertilizers, insecticides, fungicides and herbicides seem good, but the idea has drawbacks. Pesticides and fertilizers are not always needed in the same place at the same time. Applying those pesticides that are not needed wastes money and is not an ecologically sound practice. Use the best pesticide for a specific pest only when it is present and causing problems. When using fertilizers and pesticides together, make sure they are compatible.

SYSTEMIC PESTICIDES

Systemic pesticides are absorbed by and moved within plants. Systemics reach hidden, hard-to-reach pests like fungi that grow inside plants, leaf-curling aphids, tip moths and leaf mining insects. Common, foliar applied systemics are Bayleton, benomyl and acephate. Soil-applied systemic insecticides include Metasystox-R, Di-Syston and Furadan. They are used when spray drift is a concern as they are picked up by roots and translocated in the xylem to actively growing tissues to control leaf or needle-feeding insects. They do not usually control scales and borers that feed on the phloem of woody plant tissues. Most soil-applied systemic insecticides are highly toxic, restricted-use pesticides. If pest problems are serious and spraying is unacceptable, use trunk injections. These are most effective on actively growing trees before pest outbreaks are serious. Trunk injected pesticides inevitably create wounds. To avoid excessive injury, do not use injections repeatedly.

SPRAY ADJUVANTS

Improve spray performance with additives or adjuvant. They control pH, prevent pesticide hydrolysis, improve coverage, increase retention or improve pesticide performance. The products include buffering agents, surfactants and stickers.

Buffering agents are used to counteract Utah’s high-pH soil and water that increase pesticide breakdown rates. For example, carbaryl (Sevin) hydrolyzes ten times faster in water of pH 8.0 than in neutral, pH 7.0, water. Premature pesticide breakdown reduces control and/or in- creases plant injury if spray mixtures are held for several hours before use.
Surfactants, or surface-active agents, improve spray deposition and surface coverage. Treating waxy or hairy leaf surfaces is difficult without surfactants. Injury increases if some surfactants are used on sensitive plants.
Stickers: Add sticking agents to improve foliage adherence if rain or irrigation will wash pesticides off.

SOIL FUMIGANTS

Soil fumigation is used before planting to treat persistent soil organisms. Since fumigation is costly, it is used on high-value crops or where more than one disease, nematode insect, or weed must be controlled. Almost all fumigants are restricted use pesticides that require special skills licenses. Contact a fumigation specialist for appropriate fumigant selection and applications.

Fumigation requirements:

- Tilth: Fumigants are volatile toxins that diffuse through soil. Cultivate soils to the desired control depth.
- Organic matter: Fumigants are actively absorbed by organic matter. Excess debris reduces effectiveness.
- Moisture content: Excess moisture blocks fumigant movement, but most need moisture for best results. Ideal soil is moist enough for seeding but not saturated.
- Temperature: Fumigants are most efficient at soil temperatures of 50-85 degrees F.
- Waiting Periods: Fumigants are highly toxic. Depending on soil and chemical type, fumigated sites must be aerated for days or weeks before seeding.

Fumigant Uses

Nematode control: Rotations of three years or more usually lowers pathogenic nematodes to levels that cause little or no economic loss. Where serious nematode damage is suspected, test soil to see if numbers are high enough to justify fumigation.

Serious nematode damage is rare in Utah except in the St.George area.

Disease control: Treat greenhouses and nursery beds for damping off, other seedling diseases or verticillium wilt. Use plastic sheeting for fumigation with volatile compounds like methyl bromide. Water seals suffice with some chemicals. Fumigate soil infested with crown gall, phytophthora or verticillium wilt before replanting.

SEED TREATMENTS

For a more complete discussion, see the UDAF study guide on seed treatments. Germinating seeds are highly susceptible to damping off infections that destroy seeds and kill young, emerging stems. Chemical treatments protect germinating seeds and young seedlings. Most seed-treatment chemicals act only on the seed surface and nearby soil. Some systemic chemicals penetrate to kill pathogens within the seed and developing seedlings. Pathogens, such as verticillium and fusarium wilt pathogens, are soil-borne. They spread in contaminated soil, cuttings, transplants, tubers, roots and bulbs. Once in the soil, they live for years even without host plants and are almost impossible to eradicate.

PESTICIDE PHYTOTOXICITY

Pesticide applications that cause plant injuries are phytotoxic. Phytotoxicity creates abnormal growth, leaf drop and discolored, curled and spotted leaves. Severe phytotoxicity kills plants. Phytoxicity causes can be obvious or subtle and mimic insect damage, plant diseases, and poor growing conditions such as insufficient moisture and improper fertilization. Avoid plant injury when using herbicides. Some herbicides leave residues in spray tanks that injure desirable plants. Use separate sprayers for herbicides. Phytotoxicity is more severe with certain plants, pesticide drift, pesticide persistence beyond the intended control period and improper application rates or techniques.

Factors that contribute to pesticide phytotoxicity include:

- High air temperatures during and immediately after pesticide applications
- Pesticide drift
- Excessive pesticide application rates
- Too little water.
- Uneven pesticide distribution.
- Mixing fertilizers with pesticides.
- Mixing liquids or emulsifiable concentrates (EC) with wet-able powders (WP). WP formulations are less likely to injure plants than EC formulations because they are not dissolved in oil.
- Using stickers, spreaders, and wetting agents can increase damage.
- Variety and species differences.

- Pesticide mixture incompatibility can produce phytotoxicity problems. Incompatibility is likely if oils, copper or sulfur compounds are included in the mix.

PESTICIDE PERSISTENCE

Residual activity varies greatly among pesticides. Persistence is directly related to application rate, soil texture, temperature, moisture and other factors. Applicators must be familiar with pesticide persistence of products where adjacent areas may be affected, where treated soil is used to grow other plants, or where humans and pets frequent the area. An example of a persistence problem is using a highly toxic systemic insecticide on plants just before they are sold to the public. While selecting plants, individuals could be exposed to pesticides. Plants must not be offered for sale until the chemical has lost its toxicity. The time required is found on the label. Successful pest control requires knowing the persistence period before making applications. For example, herbicides used for pre-emergent weed control in turf may persist for 60 to 90 days, and post-emergent herbicides last from one day to several weeks.

MINIMIZING PESTICIDE HAZARDS

Turf and ornamental pesticides are often applied near humans, pets, and other domestic animals. They must not contact hazardous amounts of pesticides in treated areas. Applicators must be alert to the hazards and prevent drift to non-target areas.

Follow these precautions to avoid problems.

- Make sure the correct yard is sprayed.
- Do not allow children or pets to remain in the area being sprayed.
- Check neighbors' yards to make sure no children or pets can contact spray drift.
- Remove toys, pet dishes and bird feeders.
- Remove clothing from the area.
- Avoid spraying lawn furniture, ponds and birdbaths.
- Close all house windows.
- Observe label restrictions for fruits and vegetables.
- Sweep or rinse away all spray puddles.
- Secure containers and sprayers before moving.

If 2,4-D or glyphosate is accidentally sprayed on flowers or shrubs, cut them back immediately to keep it from moving into the root system. Washing off or sprinkling the leaves helps little, and fertilization intensifies the action.
Keep the herbicide away from desirable plants.

After using 2,4-D or other herbicides, do not use the same sprayer to apply insect or disease controls. Residues of herbicides are very hard to wash out, and tiny quantities left in a sprayer can damage susceptible plants.

PLANT DISEASES

A disease is anything that interferes with normal plant function. It can be biotic or pathogenic (caused by living organisms) or abiotic or nonpathogenic (caused by physiological disorders). Powdery mildew is a disease caused by a living organism. Iron deficiency is a disease caused by a physiological disorder. A disease is not a condition, it is a process. Infectious organisms, unfavorable weather, or mechanical or chemical injuries cause abnormal plant growth.

NONPATHOGENIC DISEASES

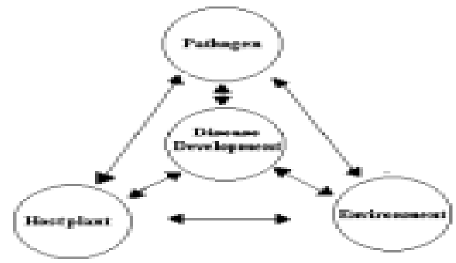
Physiological disorders from unfavorable weather, mechanical damage, nutrient deficiencies, excess salts, or toxic chemicals are not caused by pathogens. Most plant diseases are nonpathogenic. These causes do not grow in nor move from diseased to healthy plants. Pesticides do not cure noninfectious diseases.

PATHOGENIC DISEASES

Once an infectious disease starts, the process continues until the causal agent or host plant is removed or environmental conditions prevent its development. Pathogens that cause infectious diseases grow in plant tissue and disrupt normal physiological functions. As pathogenic organisms grow, they produce billions of spores that spread to other plants, causing disease outbreaks. Disease management reduces or delays epidemics enough to let plants thrive.   Pesticides are designed to stop pathogen growth on or within host plants and to protect healthy plants. For many pathogens, no chemical treatment is currently available.

Infectious Disease Development

Infectious diseases need three conditions to develop:
• Presence of parasite organisms.
• Available susceptible hosts.
• Favorable environmental conditions for development.



Pesticides stop the pathogen development, reduce host susceptibility, or inhibit pathogen development without changing conditions favorable to the host. Favorable conditions for one disease may be unfavorable for another. Temperature extremes can favor one disease while inhibiting others. For example, white mold damages some annuals under hot, moist conditions, but is less damaging during cool, dry periods. In contrast, botrytis or gray mold occurs under moist conditions below 60 degrees F. Moisture extremes affect disease development. Fungi and bacteria prefer wet conditions to enhance spore production and release. Rose rust prefers high humidity while leaf spot in aspen or fire blight in pears requires free moisture such as dripping dews or splashing rains to spread. Light, wind, pH, fertility and soil type influence disease development. Environmental influence is important to disease development. For example, sudden temperature drops increase susceptibility to fungal cankers. Waterlogged soil increases root rots and moist conditions increase scab and leaf spot. Pathogens must complete developmental cycles with spore production, dispersal, infection and resting. Some diseases spread slowly to new hosts while others spread rapidly in a single season. Slow spreading diseases produce spores or other inoculum during the growing season and disperse them at the season's end or the beginning of the next season. Diseases that spread rapidly disperse their inoculum almost continuously. Pathogens on a few plants produce large amounts of inoculum infecting many susceptible hosts. Pathogenic diseases are caused by fungi, bacteria, viruses, nematodes, parasitic seed plants, mycoplasmas and actinomycetes. Fungi, (plural of fungus) cause most plant diseases. Pathogens get nutrients from other organisms. Pathogens living on dead material are saprophytes while those that attack live plants are parasites. Most pathogens mechanically or chemically penetrate plant tissue.

Diagnosing diseases

Distribution of diseased plants within an area provides valuable information for diagnosis. In early stages, infectious diseases rarely affect large areas but affect scattered plants or small clusters. Problems that occur suddenly and attack different plants are more likely noninfectious diseases. Diagnosing or distinguishing diseases by characteristic signs and symptoms is essential. Signs and symptoms usually show together in diseased plants. **Signs** are identifiable pathogen structures that occur with diseases. They include fungal spores, spore-producing bodies, bacterial ooze, and parts of parasitic plants. A hand lens or microscope helps identify these. **Symptoms** are plant disease reactions. They appear as dead or over- or under-developed of tissues. **Tissue Death** or necrotic symptoms come from degeneration and death of plant parts. Necrosis comes from the Greek word "nekros" meaning "dead body" and means "localized death of living tissue." Necrotic symptoms and their definitions are as follows:

- Scorch or burn: Sudden death and browning of large areas
- Streaks and stripes: Elongated, narrow, parallel necrotic lesions associated with leaf veins
- Net necrosis: Irregular interlocking necrotic lines
- Blight: Foliage or blossoms suddenly killed by pathogenic organisms
- Blast: Blighting or sudden death of buds, flowers or fruit
- Die back: Dying back from tips of twigs or branches
- Spot: Circular, dead areas on foliage
- Shot hole: Dropping out of necrotic tissue from foliage, leaving circular holes
- Pitting: Depressions of dead fleshy tissue under intact skin of fruits and tubers
- Mummification: Dried, wrinkled, rotted fruits that stay on the plant
- Rot: Decomposing dead tissue
- Canker: Sunken necrotic lesions on stems, tubers or roots
- Damping-off: Rot at the stem base so the plant falls over
- Leak: Soft rot in which juices leak out
- Bleeding: Chronic flow of sap (often fermented) from wounds
- Scald: Blanching of surface tissues, giving a pale or dirty brown color
- Gummosis: Viscous gum which oozes from wounds
- Resinosis: Abnormal exuding of resin

Tissue underdevelopment involves stunting, lack of chlorophyll, or incomplete development of plant parts. Their descriptions include:

- Chlorosis: Lack of chlorophyll or green color as in yellows or mosaics
- Etoliation: Spindly growth
- Abortion or atrophy: Halt in development of flowers and fruit
- Growth Suppression: Complete prevention of development of organs
- Dwarfing, rosetting, etc.: Stunting or tightly suppressed growth

Tissue overdevelopment involves galls, swellings, cell enlargement or abnormal multiplication. Their descriptions include:

- Abnormal organs: Development of rudimentary or latent plant parts
- Premature growth: Development of shoots from normally dormant buds
- Tissue transformation: Transformation of tissues or organs
- Abnormal coloration: Atypical organ or tissue color development
- Gigantic growth: Tumor formation, callus, curl, scab, gall and root knots

INSECTS AND RELATED PESTS

Insects thrive in deserts, rain forests, hot springs, snow and caves. They live in the air, soil and water. Not all insects are pests. Many pollinate plants or feed on other pests. Most cause no harm and relatively few eat our foods, destroy useful plants or cause discomfort or poor health. Some insects damage ornamental plants and turf. They feed on and tunnel in leaves, roots, stems, seeds and nuts. They carry diseases and suck the sap from leaves, stems, roots, fruits and flowers. These activities damage, weaken or kill plants leaving unhealthy or unattractive ornamental plants. Insects continue their damage after plants are harvested, stored and processed.

COMMON INSECT CHARACTERISTICS

Knowing insect classification, growth and development, and life cycles is necessary to control pests effectively. Understanding insect life cycles allow intervention at the most effective time. Always attack them during the "weakest link," the most vulnerable point in an insect's life cycle.

Insect Classification

All adult insects have three body segments: head, thorax, and abdomen. Six, jointed legs extend from the thorax. Insects are classified by mouth and wing structure.

Mouth Parts

Mouths are adapted for piercing and sucking, chewing, sponging, and siphoning.
Piercing and sucking mouths have long slender tubes to force into plant or animal tissue to suck out fluids or blood. Stable flies, sucking lice, bed bugs, mosquitoes, true bugs, and aphids are piercing-sucking insects.
Chewing mouths have toothed jaws to bite and tear. Ants, beetles, caterpillars, and grasshoppers are chewing insects.
Sponging mouths have tubular tongue-like structures and spongy tips to soak up liquids or soluble food. Insects may extrude digestive fluids onto the food before sponging. Houseflies, flesh flies, and blow flies are sponging insects.
Siphoning mouths have a long tube for sucking nectar. Insects coil the siphon tube when not in use. Butterflies and moths are siphoning insects.

Wings

Some adult insects have no wings, while others have two or four. Wings vary in shape, size, thickness and structure. Forewings take many forms. Beetles have hard, shell-like wings while grasshopper wings are leathery. Fly forewings are membranous and those of the true bugs are part membranous and part hardened. Most insects have membranous hind wings. The wings of moths and butterflies are membranous but covered with scales.

Metamorphosis

Metamorphosis represents changes in shape, form, and size during life stages. It is incomplete or complete. Insects with incomplete metamorphosis hatch from eggs and develop into wingless nymphs. Nymphs are smaller than and look like the adults, as they undergo small changes to develop into winged, mature adults. Insects with complete metamorphosis have four developmental stages. Eggs hatch into larvae (worms, caterpillars, grubs or maggots). Because of feeding habits, the larval stage is the most damaging. Larvae change to a resting stage or pupae. They eat nothing during this stage, but undergo a major transformation, to emerge as mature winged adults that can lay eggs.

PEST MANAGEMENT STRATEGIES

Management or control of insects and related pests is vital to growing plants in Utah. But insecticides are often overused. Do not apply them in high dosages, on a calendar basis, or whenever insects appear. Not all insects are harmful and not all harmful ones need to be controlled. Never apply pesticides unless pests are causing damage. Determine if damage is reaching aesthetic or economic thresholds and consider IPM for appropriate controls.

Signs of Insect and Mite Presence

Insect or mite pests may not be present or visible when damage is discovered. Look for signs of their presence.

- Silk shelters: usually do not enclose foliage. Caterpillars feed outside the shelter and use it for protection from predators, weather, etc.
- Web enclosed foliage: silk webs enclosing foliage with caterpillars feeding inside.
- Insect or mite remains: egg shells, shed skins, cocoons, frass, and trails of silk.
- Scale and aphid covering: most scales and some aphids excrete a protective waxy covering.
- Honeydew: sticky liquid sugar excreted by insects. Black, sooty mold may grow on honeydew.
- Sawdust, wood chips, and pitch balls: material on or below trunks from feeding by bark beetles, wood borers and shoot borers.

Natural Controls of Insects and Mites

Important natural controls for some pests in Utah are:
- Spider mites: predatory mites, minute pirate bugs, ladybird beetles, predatory thrips
- Aphids: wasps, ladybird beetles, syrphid flies, lacewings
- Scale: wasps, ladybird beetles, lacewings
- Leaf beetles: wasps, fungal diseases, spiders, stink-bugs
- Bark beetles: fungal diseases, wasps
- Gall midges: wasps, predatory midges
- Tussock moths: wasps, virus diseases, tachinid flies, spiders
- Tip moths: wasps, tachinid flies
- Leafrollers: wasps, tachinid flies, spiders
- Leafminers: damsel bugs stink bugs, wasps

Biological Controls

Bacillus thuringiensis or Bt is a bacterial disease organism manufactured and sold as a “microbial insecticide” under many trade names: Dipel, Thuricide, Javelin, etc. Bt is considered nontoxic to humans, pets and wildlife. It is exempt from food crop tolerance standards and can be used up to harvest. Bt is highly specific, and most formulations only affect leaf and needle-feeding caterpillars.
It is a stomach poison and insects must eat it. Predators and parasites and insect pollinators are not affected.
Thorough coverage is essential when using Bt. Insects may not die for two to three days, but they stop feeding within hours after eating treated foliage. Researchers are developing Bt strains effective against other pests such as elm leaf beetle.
Parasitic nematodes are biological insect controls. They invade and kill susceptible insects. They need moist conditions, and are most useful to control white grubs, billbugs, sod webworms, root weevils, and crown borers.

Mechanical Control

Mechanical controls reduce pests using devices that affect them directly or alter their physical environment. They include hand picking and trapping or using screens, barriers, sticky bands, and shading devices. Using them requires time and labor and may be impractical on a large scale.

Pheromone traps: Sex attractants or pheromones have been identified for many insects and many are produced synthetically as lures to trap insects. Insect pheromones used in traps are those produced by females to attract males. The traps monitor insect flights that vary at different locations and seasons. Usually flights can be correlated with egg laying, allowing proper control timing. Pheromone trapping of lilac/ash borer, peach-tree borer, codling moth, and gypsy moth is widely used.

Light traps: Light traps or “bug-zappers” are widely sold but research shows they have no value for controlling insect pests outdoors. Few insects caught in the traps are pests and most are beneficial or harmless. These light sources also attract insects from surrounding areas.

Legal Control

Government entities can quarantine or restrict movement of potential pests into an area or use public resources to eradicate, prevent, or control pests. For example, gypsy moth control projects use public funds to prevent pest invasions.

Cultural Control

Growing practices reduce pest populations by creating unfavorable environments. These include favorable planting locations, trap crops, tillage, clean culture, timing and resistant varieties. Knowing pest life cycles is essential for effective cultural controls. Cultural controls change the environment during the vulnerable parts of pests’ life cycle to kill them or slow their reproduction. Cultural methods are aimed more at prevention than cure.

Reproductive Control

Reproductive control reduces pests by physical treatments or substances that cause sterility, alter sexual behavior or otherwise disrupt normal reproduction.

Chemical Control

Using chemicals to reduce insect populations by poisoning, attracting or repelling them is still the most common pest management tool. They are highly effective and economical, and offer quick control. When populations approach economic or aesthetic thresholds and natural controls are inadequate, pesticide applications can be the best control. Chemicals control multiple species of pests with a single pesticide application — an advantage in using insecticides in ornamental ecosystems. Chemical pesticides are important short-term pest management tools if used correctly with other ecosystem elements. Apply chemicals when pests are most vulnerable, usually when they are young. For example, control bagworms in late spring just after they hatch, or scale insects in the "crawler" stage before they develop waxy coverings. Apply chemicals where the pest spends most of its time. For example, spray undersides of leaves to control white flies.
Many insect and mite species go through multiple generations in a season. Unless the population is controlled in earlier generations, pests can increase to damaging levels as the season progresses. Most insecticides only last one to four weeks and must be reapplied for later generations.

Oils for Insect and Mite Control

Pest control oils are highly refined; specialty sprays with impurities that can damage plants. The degree of refinement appears on spray-oil labels as the unsulfonated residue percentage. Spray oils have a purity value of 90 percent or higher and a relatively low, thin viscosity. "Superior," "Supreme" or "dormant" are names of pest control oils. Oils suffocate insects and mites by clogging breathing spiracles or pores. Spray oils are often used as dormant oils to control scale, aphids or mites that over-winter on woody plants. Apply dormant oils on warm spring days before buds break. Thorough coverage is essential for effective control. Oils are safe and easy to handle and relatively safe for predators and parasites. They are effective on certain hard-to-control pests such as scales and leaf-curling aphids. Use oils cautiously as some plants are injured by them. Black walnut, some maples, Russian olive, junipers and redbud are oil-sensitive plants. Blue spruce tolerates treatment, but loses the waxy bloom which gives the distinctive color. Always use oils according to label instructions.

Soaps for Insect and Mite Control

In recent years, environmental interest and awareness have increased use of soaps as insecticide/miticides. They control most small, soft-bodied insects and mites like aphids, thrips, psyllids and spider mites as well as larger insects like honey locust plant bugs and pear slugs. Insecticidal soaps have several advantages. They are safe and easy for applicators to mix and apply. The insecticidal activity of soaps is specific so most beneficial insects, parasites and predators are not adversely affected. Likewise, birds, pets, and wildlife are not injured by treatments. Insecticidal soaps have limitations. Some plants are injured by soaps. If the safety of soap for a specific plant is not known, test it first. Apply soaps thoroughly, since they act strictly as contact insecticides with no residual activity. They do not control pests like caterpillars and leaf beetles.

Slug and Snail Control

Slugs and snails are mollusks, not insects. They are active at night and chew holes in leaves or stems. Damage can be confused with caterpillar injury. Caterpillars leave large droppings on plant foliage. Slugs leave shiny streaks of dried slime on plants and soil. Slugs chew completely through a leaf or stem. Caterpillars may leave part of the leaf veins and stems untouched. Slugs have both male and female organs in the same body and may act as males and/or females as adults. Self fertilization is also possible. They lay eggs in moist locations in clusters of 20 to 100. Mulch, boards or rocks provide cool, moist conditions for hiding and egg laying. At 50 degrees F, eggs hatch in less than 10 days and mature in three months to a year. Offspring are smaller and lighter colored but resemble adults. Control them with molluscicides and sanitation. Carefully inspect imported plants, eliminate weeds, improve watering practices and eliminate hiding places.

WEEDS

COMMON WEED FORMS

Most weeds can be placed into five convenient groups: annual grasses, perennial grasses, annual broadleaf plants and perennial broadleaf plants and woody plants. Woody plants are further divided into shrubs and trees. Shrubs have multiple stems and are less than ten feet tall, while trees are usually single stemmed and more than ten feet tall. Knowing the life cycle and classification is important for control.

Summer Annuals grow from seeds that sprout in the spring, and mature and reproduce before dying in the winter. Common summer annuals are barnyard grass, puncture vine, Russian thistle and pigweed.
Winter Annuals germinate in fall or winter and flower, produce seed and die in the spring. Common winter annuals are annual bluegrass, chickweed, mustard and wild oats.
Biennials require two years to complete their life cycles. These plants grow vegetatively (without flowering) the first year. In the second year the plants flower, produce seed, and die. Common biennials are musk thistle, mullein and hounds tongue.
Perennials live three years or longer. These plants flower and set seed without dying. Most die back in the winter but resume growth in the spring. Common perennials are quack grass, field bindweed, dandelion and plantain.

WEED CONTROL

Weed control does not always require herbicides. Avoid using them in areas with sensitive plants. In some locations, any plant cover is better than bare ground. Using chemical controls requires a thorough familiarity with weeds, the desirable plants and knowledge of herbicide usage. Follow label directions and apply herbicides at the correct time to achieve good control.

Target Weed Groups

Broadleaf Weeds

Several post-emergent herbicides selectively control annual, biennial and perennial broadleaf weeds. They are used alone or in combinations. Spring and fall applications give satisfactory control and reduce the damage possibility to desirable plants. Spot treatments are most effective for scattered weeds.

Grass Weeds

For general annual grass infestations, treat with pre-emergent herbicides. Spot treat with post-emergent herbicides for local infestations. Few herbicides are safe on newly seeded turf and ornamentals. Some pre-emergent herbicides adversely affect grass germination later in the season. Some grasses are prone to herbicide injury. Check labels for precautions. Perennial grass weeds are hard to control in turf. No herbicides are available to control these weeds without damaging cool season turf. Some selectively control them in warm season turf. Soil fumigants and nonselective herbicides also kill desirable grasses.

Herbicide Chemical Group

Devising a simple classification scheme for herbicides is difficult, because many chemicals, exhibiting a variety of modes of action, are used as herbicides. Classifying herbicides by chemical group requires at least 20 different categories. Only the most common are mentioned here.

Inorganic Herbicides

Chemical compounds that do not contain carbon are inorganic. They include salt, copper sulfate, sulfuric acid and sodium chlorate. These herbicides are extremely persistent and cause serious soil pollution problems. Many are restricted-use pesticides.

Organic Herbicide

These are divided into petroleum oils and synthetic organic herbicides.
Petroleum oils, refined from crude oil, are used as either herbicides or insecticides. When used as herbicides they are applied without dilution.
Synthetic organic herbicides are made of carbon, hydrogen and other elements. Common synthetic organic herbicides are 2,4-D and paraquat.

Selective Herbicides

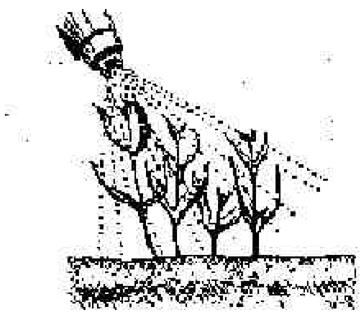
Selective herbicides control some weeds without injuring other plants. None are totally selective and may damage desirable plants. Identify weeds and apply the proper chemical at the right rate and time. Examples are 2,4-D, picloram, dicamba, and bromacil
.

Nonselective Herbicides

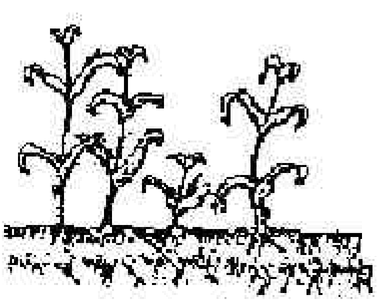
Nonselective herbicides are toxic to all plants. Toxicity depends on rate and application method. Nonselective herbicides provide bare ground areas to reduce fire or safety hazards, protect structural damage, eliminate pest breeding areas and improve security. They can be soil, contact, or translocated products. Examples are bromacil, diuron, paraquat and glyphosate. Wind, water and soil erosion can move herbicides before the chemicals fix in the soil. Prevent surface movement that can damage to adjacent, desirable plants. Herbicides seldom move off-target when applied to pavement cracks. Do not apply nonselective herbicides to slopes greater than 6 to 1, horizontal to vertical, without erosion protection.

Contact Herbicides

Contact herbicides cause localized injury to plant tissues. They are applied when the plants have leafed-out. Good coverage is necessary since only covered areas are controlled. For example, some herbicide formulations will wet broad-leaved plants but run off grasses with narrow, vertical leaves. Most are nonselective. Examples are paraquat and diquat.



Spraying visible plant foliage starts the action of a contact herbicide after growth has started.



Herbicide is taken into the plant leaves, and interferes with growth. The plant curls, withers, and turns brown.

The above ground portion dies. Some will not come back. Some may re-grow from roots. New weeds may grow from seeds in the soil.

To apply contact herbicide, spray foliage after growth starts. Leaves absorb the herbicide which interferes with growth. The plant withers and turns brown. Above ground growth is eliminated but weeds grow from roots and seeds left in the soil.

Translocated Herbicides

Translocated herbicides move in the plant. Most are selective. Some are applied to foliage, others move from soil through roots. Selectivity of translocated herbicides depends on differences in species biochemistry; some are affected and others are not. The herbicide is translocated to growing points, causing the plants to die. Determine control effectiveness by chemical, rates, rainfall, and soil. Examples are 2,4-D, picloram, bromacil, and dicamba.

Pre-emergent herbicides

These are applied before emergence of the species to be controlled. Products are applied to soil and they translocated into the plant as new shoots emerge.

Post-emergent Herbicides

These are applied after weed emergence. These are generally applied to foliage as contact or translocated herbicides.

Examples are 2,4-D, glyphosate and dicamba.

Growth regulators

Regulators control or modify plant processes without damaging the host or other plants. They are generally foliage applied and not persistent. They include defoliators, dessicants, and sprout inhibitors.

Plant Forms and Herbicides

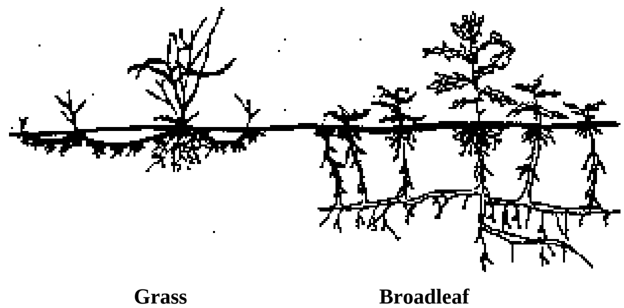
Grasses and broadleaf weeds begin as seedlings, develop vegetatively, produce buds and flower, and reach maturity. Seedlings are similar for annual, biennial and perennial weeds. While small and tender, they are easiest to kill with either mechanical or chemical controls.

Annuals and Biennials

Vegetative

During vegetative growth, plants produce stems, leaves and roots. Control at this stage is still possible, but is more difficult than with seedlings. Cultivation, mowing and post-emergent herbicides are effective

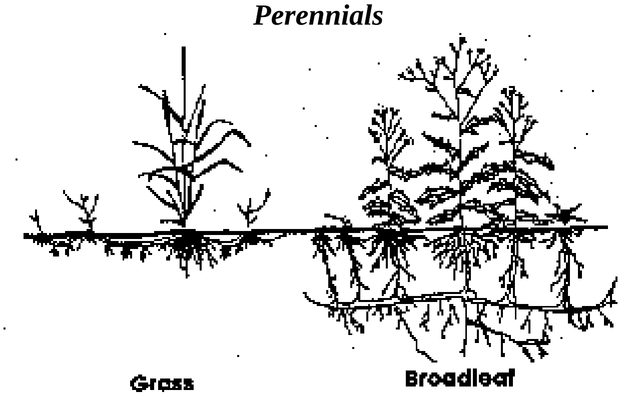
Vegetative Annuals and Biennials



Bud and Flowering

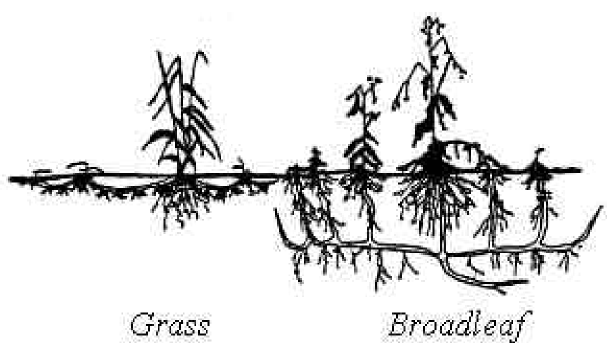
At this stage, plant energy produces flowers and seeds. They begin to store food in the roots during these stages and continue through maturity. Chemical control is more effective at the bud stage on some plants and the flowering stage on others.

Flowering Perennials



Maturity

Only the above-ground portions of perennials die each year. Underground roots and stems live through the winter and send up new growth in the spring Chemical control is usually ineffective at this stage.



Woody Perennials

Woody plants go through the same growth stages as other perennials. They do not die back to the ground during the winter, but deciduous trees lose their foliage. Herbicide control is possible but it is most effective when these plants are small and on new growth. Use foliar treatments whenever they have actively growing leaves. Both flowering and woody perennials can be controlled in the fall if herbicides are applied as the plants move nutrients from the foliage to the roots. Herbicide applications are best made just before the first frost.

Location of Growing Points

Grass growing points are protected below the soil surface. Plants re-grow if herbicides or cultivation do not reach the growing point. Creeping perennial grass buds are below the soil surface. Many woody plants sprout wherever buds are found on the roots, trunks and limbs. Seedling broadleaf weeds have an exposed growing point at the top of the young plant and in leaf axils. Herbicides and cultivation control seedlings effectively. Established perennial broadleaf plants are hard to control because they have many buds on the roots, stems and crown.

Herbicide Characteristics

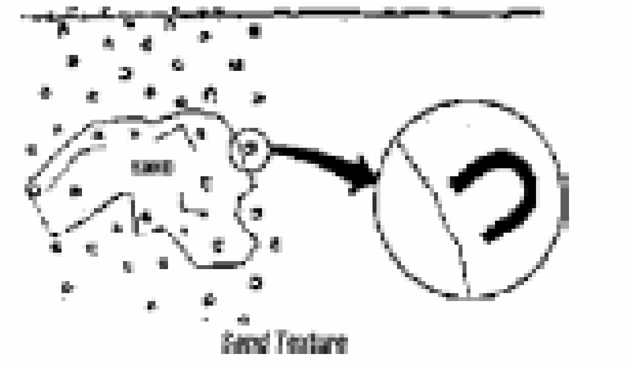
Soil Particle Tie-Up: Many herbicide particles have positive or negative charges. Those without charges move through the soil quickly. Those with positive charges tend to tie up with negative charged soil particles.

Leaching is the movement of herbicides in water through soil due to herbicide characteristics and soil factors. Herbicides vary from insoluble to completely soluble.

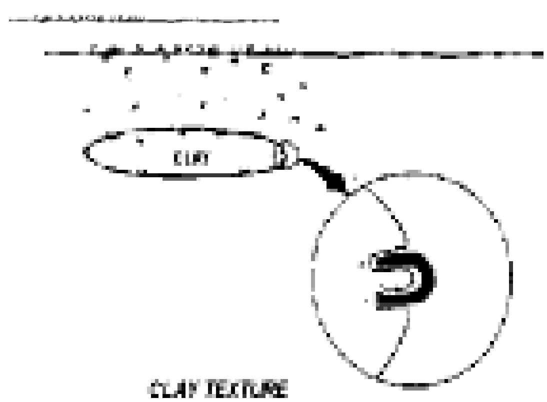
Persistence of herbicides depends on characteristics, application rates, soil texture, organic matter, precipitation, temperature, and surface flow. Herbicides can remain concentrated at the surface, partially leach, or move from the soil surface, allowing weeds to grow.

Soil Type

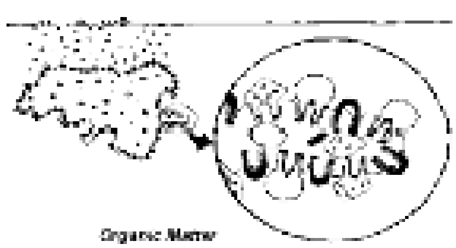
Soil texture (proportions of sand, silt and clay) and organic matter in the soil affect herbicide movement. **Sand** is coarse with few charge sites. The drawing shows a magnified sand particle. The magnet-shaped particles are herbicide molecules moving through soil. The magnified circle shows herbicide moving past the sand. It is not attracted to the particle. Silt has more sites than sand but fewer than clay and organic matter.



Clay particles are very small with many attraction sites. The drawing shows a positively charged, magnified herbicide attracted to the negatively charged clay particle. It is tied up and will not move in the soil.



Organic Matter — Organic matter has the most negative charged sites. The magnified circle shows herbicide particles tied up on the organic matter.



Coatings

Species and physical characteristics affect herbicide absorption. Wax and cuticle formation affect the way weeds absorb chemicals since herbicides must penetrate the leaf surface. Thin leaf cuticles allow good penetration. Spray solutions stand up in droplets on leaves with thick waxy surfaces. Apply herbicides while plants are young because the wax and cuticle are thinner. Hairs on leaf surfaces reduce spray absorption. Droplets are suspended on hairs above the leaf surface. Seedling weeds have fewer, shorter hairs favoring early control.

Leaf Shape and Maturity

Leaf shape affects herbicide use. Herbicide sprays run off plants with narrow, vertical leaves. Broader leaves hold the spray. Use an adjuvant to increase retention. Plant development is another important consideration. Seedling weeds are easier to control than larger weeds.

Environmental Factors

Soil Moisture: Soil-applied herbicides need moisture as precipitation or irrigation to be taken up by plant roots.
Temperature: Temperature determines plant growth rate and how they take up and translocates herbicides. At low temperatures, plants are inactive and will not take up herbicides. At very high temperatures, herbicides can evaporate (volatilize).
Humidity: Foliar herbicides enter the leaf more easily and rapidly in high humidity. With humidity the leaf is tender and has thinner wax or cuticle layers.
Precipitation: Precipitation soon after a foliar treatment decreases effectiveness. Precipitation after soil application activates soil herbicides. Too much rain moves herbicide past the root zone. Excess water moves surface applied herbicides on slopes.
Wind and Temperature: Hot, dry winds cause plant surface openings to close, leaf surfaces to thicken and wax layers to harden, reducing herbicide penetration.

Application Methods

Apply herbicides as spot or broadcast treatments according to target pests, host plants and pesticide characteristics. Use the right equipment to apply the correct amount of pesticide where protection is needed. Use low pressure, low volume sprayers or granular applicators to control soil or foliage pests or weeds. Use high pressure hydraulic or air blast sprayers for large trees. Control individual plants in sensitive spots or small areas with hand sprayers. Spot treat small areas with hand sprayers or guns or spreaders. Broadcast application to foliage or soil is effective over large areas. Use sprayers with booms or handguns.

Drift Problems

Landscape plants vary in susceptibility to pesticide damage so applicators must prevent drift problems. The most common type of drift is spray droplets or dust particles. It is affected by spray pressure, nozzle size, wind velocity, and pesticide formulations. The distance a particle or spray can drift is determined by wind, the distance from the spray nozzle to the ground, and the size of the particle. Small particles, such as fog or mist, present the greatest hazard.

Drift of a chemical with low vapor pressure is vapor drift. Some pesticide vapors drift in harmful concentrations even without wind. Volatile pesticides, such as 2,4-D vaporize in harmful concentrations after application and damage or kill desirable plants. Vaporization is less common than particle drift, but can move farther.

To reduce drift, take the following precautions:

- Use the lowest practical pressures.
- Leave an untreated edge.
- Angle nozzles forward in the travel direction.
- Use nozzles with the largest practical openings.
- Use low-volatile formulations of the chemicals.
- Spray when wind speed is low.
- Do not spray during a temperature inversion (when air is cooler at ground level than higher up).
- Spray when sensitive plants are not actively growing.

Drift Control Agents

Special adjuvants and application systems help overcome drift problems. Most are used with agricultural or right-of-way treatments. Three of these are:

- Foams (tank-mixed, conventional formulations with an additive)
- Invert emulsions (three systems; mixed at the nozzle, mixed at the pump, or tank-mixed)
- Spray-additive stabilizers (thickeners in dry form mixed with conventional formulations in tank with agitation)

Choice of Sprayers

There are several ways to apply herbicides. Hand carried sprayers are convenient. When used properly, they pose less danger of drift than other application methods. Homeowners sometimes use garden hose sprayer attachments which can be effective in small areas. The pesticide is drawn into the attachment and mixes with water coming from the hose. They are convenient and inexpensive, but controlling drift and making even, accurate herbicide applications is difficult, so do not use them with herbicides.

Wax bars impregnated with 2,4-D reduce problems. The 2,4-D rubs off the bar onto weeds with no drift or volatility. For touch-ups, soak a sponge, rag or paint brush with herbicide and dab it on weeds. Use a pint or quart-size atomizer/trigger bottle to spray individual plants or small areas. Pesticides also are available in pressurized cans. Many weed killers are sold as dry formulations and applied with fertilizer spreaders.

ORNAMENTAL PEST CONTROL

Woody Plant Pest Management

Many different insects and mites feed on woody plants.

The greater the variety of plants, the more insect and mite species are present. This is not always a problem because a variety of plants limits pest outbreaks that seriously damage or destroy plantings of only one species. Some plants require frequent controls while others are have few pest problems. Insects or mites do not signify a problem that must be controlled with pesticides. Wasps, lady beetles, and other organisms keep many pests under control. These are not always effective, requiring intervention with chemical or other controls. In Utah, some pests thrive and cause trouble every year because they have few natural enemies. Use non-chemical controls when possible. Sanitation, pruning, resistant varieties, and hand removal are important pest controls. Remove and destroy infested plants. Dead plants are breeding sites for insects that attack other plants. Learn to recognize common insects and mite pests. They are grouped by plant parts they feed on — leaves, twigs, trunks or roots — and as chewing or sucking pests.

Leaf Feeders

Deciduous plants tolerate some defoliation without affecting tree vigor. Late season defoliation of deciduous trees and shrubs is less damaging because trees have produced and stored food necessary for growth. Leaf feeding defoliators include butterfly, moth, beetle and sawfly larvae. Late season defoliation of evergreens is more damaging because evergreens store food in needles and leaves. Destroying new annual growth is damaging since it is most efficient in producing plant food. Destroying new growth makes trees miss one-third of the needles for three years because needles last for several seasons on most species. Many caterpillars feed on the foliage of trees and shrubs, but only a few are serious pests in Utah. Some form unsightly webs on branches, justifying their control. Most pest caterpillars in Utah have one generation per year. Leaf beetles do most of their damage during the immature larval stage. The insects consume all but the veins, leaving leaf skeletons.

Wood Borers

Wood boring insects are among the most damaging tree pests. Some attack living plants and others attack dead or severely stressed plants. Three common groups cause damage. Long-horned beetles, known as round-headed borers in the larval stage, make deep tunnels and structurally weaken infested trees. Metallic wood borers, known as flat headed borers in the larval stage, tunnel under the bark and make galleries that girdle trees. Clear-winged borers are moths with larvae that develop at the base of the tree. Controlling borers is difficult as they are protected inside the tree. Make preventative trunk sprays before borers deposit eggs on the bark. Use pheromone traps to determine flight times of clear-winged moths like the ash/lilac borer and peach tree borer. Since pheromone traps or wood-boring beetles are not available, carefully observe adults to time treatments. Metallic wood borers lay eggs in May, June and July and long-horned beetles lay eggs in July, August and September. An alternative to spraying is to locate and destroy borers with a sharp probe. Avoid making additional wounds. Prune out and destroy infested branches before adults emerge. Many borers enter trees near wounds. Prune properly to help wounds close rapidly.

Use cultural practices that promote vigorous plants. Healthy trees are less attractive to borers, tolerate damage that does occur, and use natural defenses to prevent their invasion.

Shoot Borers

Tip moths and various beetles feed on the surface or inside conifer shoots, causing abnormal growth and death. Control shoot borers during egg laying and hatching when eggs or larvae are exposed on the bark.

Plant Galls

Galls are abnormal growths caused by insects, mites, diseases and hormones. Due to unusual shapes and colors, galls cause concern but serious damage is rare. Gall formation varies seasonally due to natural controls. Gall-making insects and mites produce galls during feeding and egg laying. Since only new growth is susceptible, most galls form in late spring as leaves develop. Most treatments are to improve appearance. Time controls to coincide with egg hatch and feeding. Treat those that over-winter on the plant prior to bud break.

TURF

Utah’s turf industry includes parks, home lawns, sod-farms, institutional and industrial grounds, golf courses, athletic fields, roadsides, and cemeteries. Home lawns make up the largest segment of the industry. Grass is used for beauty and recreation, erosion control, and utility purposes. Most consumers like and take pride in maintaining attractive, quality turf. Attractive turf needs proper management to provide good color and density and freedom from weeds, insects and diseases. Good management includes the right grass, mowing, watering, fertilizing, and thatch control. Pesticides are not substitutes for good cultural practices. Do not use them to offset improper watering, fertilization, mowing height and frequency, thatch accumulation, poor soil, or poor species choice. Utah’s harsh climate makes growing consistent, high quality turf difficult. Extreme, unpredictable moisture, humidity, soils, sun and wind stress turf in all climatic zones. Summer to winter temperature ranges limit which grasses will grow. The variable climate allows growing cool and warm season grasses in the state.

Because both cool and warm season grasses grow in Utah, pesticide applicators must be able to identify and care for them. Some problems are specific to species. Chemicals are formulated for warm or cool season turf. The wrong grass in the wrong situation creates problems that are hard to solve, even with proper management and pesticide applications.

PREVENTIVE MAINTENANCE

Magic formulas for producing good lawns do not exist. Like all plants, grasses need optimal amounts of light, moisture and nutrients. They are also subject to pests. Not all lawns are affected by the same pests. Even within the lawn, some areas are more prone to damage. Not all lawns need the same cultural intensity. Turf care depends on species, desired quality, intended use, time, effort and money available.

These cultural practices help reduce or prevent pests and aid plant recovery.

- Select species or cultivars adapted to the site and the intended use.
- Ensure proper soil conditions, including adequate surface and subsurface drainage.
- Establish turf correctly.
- Water properly. The longer grass is wet, the greater the possibility for disease problems. Apply enough water at one time to provide adequate moisture for a week and wet the soil six to eight inches deep.
- Remove thatch that is more than one-half inch deep.
  Thatch is a tight layer of living and dead stems and grass roots that develops between the leaves and soil surface. Too much thatch keeps water from penetrating the soil, prevents deep rooting and makes some pest problems worse. Thatch is often an ailment of intensive turf care. Grasses differ in their inclination to develop thatch.
- Mow upright grasses, such as bluegrass and fescues to 2½ inches or higher in the summer. Creeping grasses such as bent, Bermuda and zoysia can be mowed to one-half inch or less.
- Mow often enough that no more than one-fourth to one-third of the leaf surface is removed at a time. Mow the lawn in the fall until grass stops growing.
- Aerate compacted areas, using hand or power equipment with hollow tines to remove soil cores that leave a hole or cavity in the soil.
- Fertilize according to recommendations and soil tests. Recommendations vary with species and use. Do not over fertilize to promote fast, lush growth.
- Follow suggested pest control programs for local conditions and grass species.

TURF PEST MANAGEMENT

The most frequent turf pests are weeds, insects, and diseases.

Rodents rarely attack turf. When diagnosing turf-grass problems:

- Determine the grass species involved.
- Find out why the problem occurred.
- Determine whether the problem is best corrected by management practices, soil modification or pesticides.
- Use cultural practices to help turf recover.
- Check chemical labels for species, site and pest.

Poor management practices contribute to turf pest damage. Incorrect watering, mowing or fertilization weakens turf making it more prone to pests. Turf damage varies, depending on species, developmental stages, and cultural practices. Injuries range from minor, temporary turf discoloration from slime mold to death from billbugs. Golf courses, sod farms, parks, and recreational facilities face significant repair and replacement costs and potential income loss. Chemicals have traditionally been favored pest control methods because of their long residual, broad-spectrum effects, and labor-saving features. Concern about the effects of pesticides on man and the environment requires a re-evaluation of this approach. The pest tolerance level varies with the situation. Species, growth stage, use, environmental conditions, and management intensity dictate acceptable levels. Homeowners may tolerate some weeds that a golf superintendent would not on a green or tee. Vigorous, healthy turf can tolerate some pests where weak turf cannot. Good pest management combines the best available methods of prevention and care. The best methods for preventing or reducing pest populations in turf are:

- Genetic: the use of resistant cultivars.
- Cultural: proper mowing, aeration, watering and fertilizing practices.
- Chemical: the use of pesticides.

All are important to prevent pests from reaching unacceptable levels. Genetics are preventive measures. Species and varieties that are resistant to pests are used for effective pest control. Chemical and cultural methods can be preventive or curative. No grass does well in every situation. Choose a species suited for the conditions rather than trying to fit the environment to the species. Blending or mixing suitable grasses helps turf under various conditions. Use good cultural practices to produce healthy turf that prevents or tolerates pests and

reduces or eliminates the need for chemical controls. When a pest is identified and the predetermined threshold is reached, all possible controls must be weighed to determine the human and environmental benefits and risks. Cost and effectiveness must also be considered. Use the safest, most efficient and economical selective controls if possible.
Chemical controls require knowledge of the pests and the turf species being grown and an understanding of correct pesticide usage, label directions and application timing.

TURF DISEASES

Poor turf is often caused by environmental and cultural conditions. Fertilizers and pesticides injure turf if improperly applied at too high or too low a rate. Micronutrients deficiencies are another cause of poor growth. Soil is essential for a healthy lawn. Take time to prepare soil properly before planting to reduce future problems. This allows water and air to penetrate and promote root growth. Aerate soil regularly to allow air penetration. Turf planted in compacted soil thins out and develops water-related algae and moss. Lawns may also require maintenance due to the impacts of animals such as dogs and rodents. In Utah, turf diseases are best controlled by cultural practices, not fungicides. Preventive fungicide use is sometimes warranted when turf has a history of disease. Time fungicide applications based on the fungus life cycle and weather conditions. Routine fungicide use to prevent disease outbreaks is expensive and potentially harmful. Use USU Extension Agents or other information sources to help identify problems and choose the correct fungicide.

TURF INSECTS

Insects and related arthropods commonly inhabit lawns in large numbers but few cause serious damage. Good management is the best defense. Healthy, unstressed grass can better produce new roots and leaves than weak grass.
Insects that damage lawns are classified as above ground or below ground pests according to their feeding damage.
Above ground pests feed on grass blades and stems. Included in this group are sod webworms, armyworms and cutworms. Foliage applied insecticides kill the insects as they crawl around or feed on the grass. Underground pests including white grubs and billbugs feed on grass roots. Insecticides are applied to the grass, then watered into the soil where the insects live.

Evaluating Turf Insect Problems

Solving insect problems requires knowing the area conditions, inspecting the grass, identifying problems, determining and applying controls and evaluating controls.

Periodic Inspection

Periodic inspections identify infestations. Look at the blades and stems. Check for above-ground insects by sprinkling a mixture of one quart of water and one tablespoon of powdered detergent over four square feet of turf. (A teaspoon of pyrethrum can be substituted for the detergent.) This brings above-ground insects to the surface within ten minutes. They can then be collected and counted. Sample several areas to get an average number of insects. To inspect for subsurface insect damage, grab a handful of grass and pull up. If the turf comes up easily, the roots are damaged. If the grass will not come up or breaks off, look for other causes. To check for root feeding insects, cut a square section of sod four inches deep on three sides, and roll it back. Shake the soil off the roots to look for the pests. Other symptoms, such as fertilizer burn, diseases, improper mowing, drought, dog urine spots and pesticide damage may resemble insect damage.

Identification

Identify insects to separate pests from those that do no damage. Some insects benefit turf by preying on pests or feeding on decaying organic matter. Others are temporary and neither harmful nor beneficial. Leafhoppers and clover mites occasionally inhabit lawns but cause no damage.

Prescription

If insect pests are found, evaluate control options. If chemicals are used, select correct products and formulations.

Application

After deciding what chemical to use, apply the insecticide when pests are vulnerable, at the proper rate. Some pests have multiple generations, so repeat applications may be needed. Always read and follow label directions.

Evaluation of treatment

Did the insecticide work? It may take two to three days to control above-ground insects and two to four weeks for soil insects. If the application did not work, find out why.

Cleanup and Storage

The job is not finished until the equipment is cleaned and the insecticide is stored properly. Store insecticides in their original containers locked in a cool, dry, clearly marked place where they will not freeze.

The Key to Major Lawn Insects

Insects feeding on roots or in crowns

A. Larvae white, usually C-shaped, with brown heads, six short legs near head region .....White grubs

B. Larvae white, usually C-shaped, with brown heads, no legs, usually 3/8" long or less… Billbug grubs

C. Larvae tan or orange, six legs on forward part of body, smooth, slender body, and usually hard and shiny..........Wireworms

Insects Feeding on Leaves and Stems

A. Larvae up to 5/16" long, gray, with definite small spots from which hairs grow ....Sod webworms

B. Snout beetles, black, about 3/8" long ....Bluegrass billbug

C. Caterpillars with six true legs on forward part of body, and fleshy pro-legs on abdomen, distinct head capsules, usually brown. May be 1" long ....Armyworms and cutworms

1. Row of small yellow or white dots down center of back........Variegated cutworm
2. Dark color, granulated skin.........Black cutworm
3. Yellow lengthwise stripes on entire body ....Bronze cutworm
4. Greenish color with distinct stripes on side of body ....Armyworm
5. Greenish or black with stripes on side of body, head with a white inverted Y on frontal portion...... Fall armyworm
6. None of the above.........Unidentified cutworm

D. Small, green or brown insects, 3/16" long, very active — jumping or flying when molested ....Leafhopper

E. Small, green soft-bodied, non-mobile insects, about 2 mm (1/16") long on leaves or stems..........Aphids

F. Very active, running on ground usually, in dry areas, small insects 3/16" long, greenish gray, usually occurring in large numbers ....False chinchbugs

Arthropods That Inhabit, but Usually Do Not Injure, Turf

A. Small, about 1/8" wide, spiral shells ....Snail

B. Dark brown, wormlike, hard-shelled creatures that usually coil when molested, have four legs on each segment..........Millipedes

C. Gray-colored, soft-bodied arthropods having 14 legs, usually in wet locations..........Sowbugs

D. Description same as above, but usually roll into small balls when molested..........Pillbug

E. Eight legs, various colors, usually brown, very active, up to 25mm (1") in body length...........Spiders

F. Large, black and yellow wasps, burrowing into soil ....Cicada killers

G. Small soil mounds, may damage grass around mound, small brown or red insects near mounds.......... Ants

Turf Weed Management

Growing acceptable turf requires good weed control. Weeds are controlled by prevention and mechanical, cultural and chemical methods. Chemical controls are highly promoted but do not substitute for good management. The best turf weed control is healthy, dense, vigorous grass. Anything that helps produce thick turf discourages weeds. Killing weeds with chemicals is possible, but without good management, the turf still looks unattractive. Every cubic foot of topsoil has thousands of weed seeds that geminate when air, light, moisture and temperature are favorable. This creates enormous numbers of weed seedlings in most new lawns. Most are unable to tolerate mowing or grass competition and disappear after the first season. Others invade unhealthy lawns where grass stands are thin. Persistent weeds are troublesome and make a lawn look unattractive. An acceptable weed level in turf varies with grass type, growth stages, use and environmental conditions. Turf managers need a clear understanding of how turf is used to develop their management plan.

SAFETY

Pesticide safety is important for applicators and those who come in contact with the chemicals before, during, or after application. Reduce pesticide risks by using them according to label instructions. Carelessly handled pesticides endanger the user, others and the environment. To avoid problems, know products and how to use them. Read labels carefully and learn about the products before applying them. Identify the insect, weed, disease, or other pests. If two products are equally effective, use the least toxic. Do not let irresponsible or careless people handle, mix or apply pesticides. Never eat, drink or smoke or carry food or smoking items when applying pesticides. After pesticide application and equipment cleaning, shower to remove pesticides from the skin and change to clean clothing. Guard against drift when applying pesticides. Some chemicals drift for miles under the right conditions. The most important factors are wind velocity and direction. Always follow label instructions for proper re-entry and pre-harvest intervals. Improperly discarded empty pesticide containers are potential hazards. Empty containers attract curious children and animals. Never let them become attractive nuisances. Avoid disposal problems with excess pesticides by buying only the amount of material needed. DO NOT STOCKPILE! Mix only the pesticide needed for an application. Dispose of small quantities of home garden products through ordinary waste collection. Leave pesticides in original containers and wrap them in several layers of newspaper. Dispose of empty pesticide containers the same way. Use excess dilute pesticide mixtures on a site listed on the label. Never store dilute pesticides. Do not dump pesticides into toilets or other drainages. Such disposal methods contaminate water supplies and sewage systems and ***VIOLATE FEDERAL LAW.*** Clean up spills or leaks immediately. Spread pet litter, or other absorbent material on the spill. Sweep it up and scatter lime over the contaminated area. Wash the area thoroughly with detergent and water. Dispose of contaminated absorbent material, lime, and wash water according to label directions. With large spills call the Department of Environmental Quality at 801-536-4123 or Comprehensive Emergency Management at 801-538-3400, 24 hours a day. Most pesticides have a low risk if properly used. User attitude is extremely important. Inadvertent misuse or carelessness injures humans, animals or plants. Reading the label will not ensure safety. Follow instructions precisely. Users who realize legal and moral obligations in using pesticides are likely to read labels and follow instructions. Applicators that take necessary precautions and practice good management prevent pesticide accidents.

WORKER PROTECTION STANDARD

The U.S. Environmental Protection Agency's Worker Protection Standard (WPS), as revised in 1992, must be complied with when pesticides are used on agricultural establishments, including farms, forests, nurseries, and greenhouses, for the commercial or research production of agricultural plants. The WPS requires employers to provide agricultural workers and pesticide handlers with protections against possible harm from pesticides. Persons who must comply with these instructions include owners or operators of agricultural establishments and owners or operators of commercial businesses that are hired to apply pesticides on the agricultural establishment or to perform crop-advising tasks on such establishments. Family members who work on an agricultural or commercial pesticide establishment are considered employees in some situations.

WPS requirements for employers include:

- **Displaying information** about pesticide safety, emergency procedures, and recent pesticide applications on agricultural sites.
- **Training** workers and handlers about pesticide safety.
- Helping employees get **medical assistance** in case of a pesticide related emergency.
- Providing **decontamination sites** to wash pesticide residues off hands and body.
- Compliance with **restricted entry intervals** (REI)– the time after a pesticide application when workers may not enter the area.
- **Notifying** workers through posted and/or oral warnings about areas where pesticide applications are taking place and areas where REI are in effect.
- Allowing only **trained and equipped workers** to be present during a pesticide application.
- Providing **personal protective equipment** (PPE) for pesticide handlers and also for workers who enter pesticide treated areas before expiration of the REI.
- **Protecting pesticide handlers** by giving them safety instructions about the correct use of pesticide application equipment and PPE and monitoring workers and handlers in hazardous situations.

One of the provisions of the WPS is the requirement that employers provide handlers and workers with ample water, soap, and single use towels for washing and decontamination from pesticides and that emergency transportation be made available in the event of a pesticide poisoning or injury. The WPS also establishes REI and the requirements for PPE. PPE requirements are specified for all pesticides used on farms and in forests, greenhouses, and nurseries. Some pesticide products already carried REI and PPE directions. This rule raised the level of protection and requirements for all pesticide products.

Other major provisions require that employers inform workers and handlers about pesticide hazards through safety training. Handlers must have easy access to pesticide label safety information and a listing of treatments site must be centrally located at the agricultural facility. Handlers are prohibited from applying a pesticide in a way that could expose workers or other people.

References: ***The Worker Protection Standard for Agricultural Pesticides–How to Comply: What Employers Need to Know***. Web site <www.usda.gov/oce/oce/labor-affairs/wpspage.htm>**.**

GROUND WATER PROTECTION AND ENDANGERED SPECIES

INTRODUCTION

Federal and state efforts to protect groundwater and endangered species have resulted in special requirements and restrictions for pesticide handlers and applicators. Pesticides that are incorrectly or accidentally released into the environment can pose a threat to groundwater and endangered species. Whether pesticides are applied indoors or outdoors, in an urban area or in a rural area, the endangered species and groundwater must be protected and state and federal agencies rigidly enforce this requirement.

The need for special action by the pesticide handler/applicator depends on site location. Groundwater contamination is of special concern in release sites where groundwater is close to the surface or where the soil type or the geology allows contaminants to reach groundwater easily. In the case of endangered species, special action is normally required in locations where the species currently live or in locations where species are being reintroduced. The product labeling is the best source to determine if pesticide use is subject to groundwater or endangered species limitations.

The U.S. Environmental Protection Agency (EPA) establishes the specific limitations or instructions for pesticide users in locations where groundwater or endangered species are most at risk. These limitations and instructions may be too detailed for inclusion in pesticide labeling. In such cases the labeling will direct the applicator or handler to another source for instructions and restrictions. The legal responsibility for following instructions that are distributed separately is the same as it is for instructions that appear on the pesticide labeling.

PROTECTING GROUNDWATER

Groundwater is water located beneath the earth’s surface. Many people think that groundwater occurs in vast underground lakes, rivers, or streams. Usually, however, it is located in rock and soil. It moves very slowly through irregular spaces within otherwise solid rock or seeps between particles of sand, clay, and gravel. An exception is in limestone areas, where groundwater may flow through large underground channels or caverns. Surface water may move several feet in a second or a minute. Groundwater may move only a few feet in a month or a year. If the groundwater is capable of providing significant quantities of water to a well or spring, it is called an aquifer. Pesticide contamination of aquifers is very troubling, because these are sources of drinking, washing, and irrigation water.

Utah has implemented a comprehensive and coordinated approach to protect groundwater from pesticide contamination. Formulation of the Utah Groundwater and Pesticide State Management Plan is a cooperative effort between federal, state, private agencies, producers, and user groups. It provides a basis for continuing future efforts to protect groundwater from contamination whenever possible. Furthermore, this plan provides agencies with direction for management policies, regulations, enforcement, and implementation of groundwater strategies.

Utah recognizes that the responsible and wise use of pesticides can have a positive economic impact, yield a higher quality of life, enhance outdoor activities, and give relief from annoying pests. The EPA has authorized the Utah Department of Agriculture and Food (UDAF) to enforce the protection of groundwater from pesticides.

The UDAF, in concert with cooperating agencies and entities, demands strict compliance with all pesticide labels, handling procedures, and usage to protect groundwater in the state.

Prevention of groundwater contamination is important, because once the water is polluted, it is very difficult and costly to correct the damage and in some instances impossible. City and urban areas contribute to pollution because water runoff can contain pesticides. Shallow aquifers or water tables are more susceptible to contamination than deeper aquifers or water tables. Sandy soils allow more pollution to move than clay or organic soils, because clays and organic matter adsorb many of the contaminants. For more information about what groundwater is and where it comes from, read the study manual ***Applying Pesticides Correctly: A Guide for Private and Commercial Applicators.***

The Federal Insecticide, Fungicide and Rodenticide Act (FIFRA), as amended, establishes a policy for determining the acceptability of a pesticide use or the continuation of that use, according to a risk/benefit assessment. As long as benefits outweigh adverse effects, the EPA can continue to register the pesticide. Although the intent of a pesticide application is to apply the pesticide to the target or pest, part of the pesticide will fall on the area around the target or pest. Rain or irrigation water then can pick up the part that is not degraded or broken down and carry it to the groundwater via leaching.

There are many factors that influence the amount of pesticide contamination that can get into groundwater. The major factors are the soil type, soil moisture, persistence in soil, placement of the pesticide, frequency of application, pesticide concentration and formulation, pesticide water solubility, and precipitation. Each of these factors will influence the amount of pesticide that can penetrate the soil surface, leave the root zone, and percolate into groundwater.

Although some pesticides may have a high adsorption quality, when they are applied to sandy soil, they may still migrate to the water table because there are few clay particles or little organic matter to bind them. The management and use of pesticides is up to the individual applicator and/or landowner as to whether safe practices are used. Groundwater is a very valuable resource and it must be protected from pesticide contamination.

PROTECTING ENDANGERED SPECIES

The Federal Endangered Species Act lists the three classifications as endangered, threatened, and experimental. Endangered has the highest level of protection. The phrase “endangered species” is used when referring to these classifications. This Act was passed by Congress to protect certain plants and wildlife that are in danger of becoming extinct. A portion of this Act requires EPA to ensure that these species are protected from pesticides.

EPA’s goal is to remove or reduce the threat to endangered species that pesticides pose. Achieving this goal is a portion of the larger continuing effort to protect species at risk. Normally these restrictions apply to the habitat or range currently occupied by the species at risk. Occasionally the restrictions apply where endangered species are being reintroduced into a habitat previously occupied.

Habitats are the areas of land, water, and air space that an endangered species needs for survival. Such areas include breeding sites, sources of food, cover, and shelter, and the surrounding territory that provides space for normal population growth and behavior.

Utah's endangered species plan is a cooperative effort between federal, state, private agencies, producers, and user groups. This plan provides agency direction for regulations, enforcement, management policies, and implementation of threatened and endangered species protection strategies.

EPA launched a major project known as Endangered Species Labeling (ESL). The goal is to remove or reduce the threat to endangered species from pesticides. EPA has the responsibility to protect wildlife and the environment against hazards posed by pesticides. The ESL program is administered by the U.S. Fish and Wildlife Service (FWS) in the U.S. Department of Interior. The FWS reports to EPA concerning endangered species. EPA and FWS work cooperatively to ensure that there is consistency in the pesticide restriction information provided to agencies and pesticide users.

The UDAF acts under the direction and authority of EPA to carry out the ESL project as it relates to the use of pesticides in Utah. Utah's web sites with maps designating the habitat boundaries and listings of endangered plants and wildlife is: www.utahcdc.usu.edu

GLOSSARY

A

Abdomen -- an insect's third body division
Absorption -- the process by which pesticides are taken into plants.
Acaricide -- a pesticide that kills mites. A miticide.
Acid soil -- a soil with a ph of less than 7.0. Active ingredient (ai) -- the amount of actual pesticide in a formulation.
Adjuvant -- a chemical added to a pesticide to improve its effectiveness.
Adsorption -- the adhesion of pesticide spray droplets to the plant surface.
Adult -- a full-grown, sexually mature insect.
Aeration, mechanical -- see cultivation.
Alkaline soil -- a soil with a ph greater than 7.0.
Allelopathic -- toxins produced by plants that injures or inhibits growth of other species.
Alternate -- bud arrangement where nodes are not directly across from another node.
Amendment, physical -- a substance added to the soil to alter physical conditions (sand, calcined clay, peat, etc.).
Annual -- a plant that completes its life cycle within one year, then dies.
Anther -- the pollen-bearing stamen parts.
Anthracnose -- a fungal disease having characteristic necrotic lesions on leaves.
Antidote -- a remedy that counteracts the effects of a poison.
Apical meristem -- terminal growth point.
Application rate -- the amount of pesticide applied to a given area.
Aromatics -- compounds derived from the hydrocarbon benzene (ch6).
Auricle -- claw-like appendages occurring in pairs at the base of the leaf blade awn – hair-like projections extending from the mid-nerve or section of a grass flower
Axil -- upper angle of the leaf and stem axis.

B

Bactericide -- pesticide that kills bacteria.
Bacteria -- microscopic, unicellular organism that reproduces by cell division.
Band application -- of spray or dust to a continuous area such as in or along a crop row rather than over the entire area.
Basal treatment -- applied to the stem of a plant so foliage contact is minimized. Describes treatment of woody plants.

Basal whorl -- groups of leaves attached at the same point at the base of a plant.
Bench setting -- the height setting of the mower bed knife above a firm, level surface.
Biennial -- a plant that completes its growth in two years. Year one it produces leaves and stores food and the year two it produces seeds.
Biological control -- of pests by living organisms such as predators, parasites, and disease producing microorganisms.
Blade -- the flattened part of a grass leaf or the leaf part that grows away from the stem.
Blend -- a combination of two or more cultivars of a single grass species.
Broadcast treatment -- application of a herbicide over an entire area.
Bug -- insects of the order Hemiptera.
Bunch-type growth -- tight clump grass growth without producing rhizomes or stolons.

C

Canker -- dry, diseased or dead area in woody tissue.
Carbamate pesticide -- a compound synthesized from carbamic acid.
Carrier -- material added to a chemical to facilitate storage, shipment, or use in the field.
Castings, earthworm -- soil and plant remains excreted by earthworms. The deposits are objectionable on closely mowed turf.
Caterpillar -- larvae of the moths and butterflies, but larvae of sawflies in the hymenoptera are also caterpillar- like.
Cell -- the organism structure unit of protoplasm that is surrounded by a cell wall.
Chlorosis (adj. Chlorotic) **--** a yellow to white or gray condition of normally green plant tissue resulting from the partial to complete destruction of chlorophyll. Chlorosis is a common symptom of iron deficiency.
Claw -- sharp, hollow appendages on insects last tarsal segment , used for clinging to objects.
Coleoptile -- protective sheath of an embryonic shoot.
Collar -- the light-colored band at the leaf blade and sheath junction on the grass leaf.
Colorant -- dye or pigment used on warm season turf in winter dormancy or cool season turf in summer dormancy or turf discolored by environmental stress, pests, or abuse.
Compatible -- qualities that permit two or more compounds to be mixed without affecting the properties of either.
Complete flower **--** having sepals, petals, stamens and pistils or male and female parts.
Compost -- a mixture of organic residue and soil that has decomposed.
Compound leaf -- one divided into two or more distinct leaflets.
Concentration -- the amount of active material in a given volume. Specifications for pesticide concentrations should be on based on pounds per unit volume of diluent.
Contact pesticide -- a pesticide that kills on contact.
Cool-season grass -- grass species that grow best at 60 to 75 degrees F.
Core aerification -- turf cultivation method that removes soil cores with hollow tines to control thatch, soil compaction and to aid in pesticides and water penetration.
Cornicles -- dorsal, tubular appendages on the posterior of the abdomen of certain aphids.
Cortex -- outer bark tissue.
Cortical -- pertaining to the cortex.
Cotyledon leaves -- the first leaf, or pair of leaves, of seed plant embryos.
Crawler -- an immature stage of adelgid or scale insects-the active, crawling stage.
Crown -- the point where stem and root join in a seed plant.
Culm -- stem of a grass plant.
Cultivar --a cultivated variety.
Cultivation -- in turf, cultivation is working the soil and/or thatch without destroying the turf, by coring, slicing or spiking.
Curculio -- beetles with slender snouts curving down and backward, with chewing mouthparts at the tip.

D

Damage threshold level -- the lowest pest population density at which damage occurs.
Damping-off -- a seedling disease where the stem decays near the soil line, either as seed rot or after emergence.
Desiccation -- drying out.
Dethatching -- removing excess thatch from turf.
Dicot -- short for dicotyledon. Plant with two cotyledons in the seed in broadleaf species.
Directed application -- a pesticide directed onto weeds or soil in a way that avoids contact with desirable plants.
Dormancy -- a state of suspended development as in inhibited seed germination of seeds or plant growth.
Dormant spray -- spray applied during the dormant season, when plants are inactive.
Drift -- pesticide movement from the intended target during application.

E

Ecology -- the study of the effect of environmental factors such as soil, climate and culture on organisms.

Economic injury level -- the lowest pest population density causing economic damage.
Eelworms -- nematodes.
Emerged -- the emergence of the adult from the cocoon, pupal case or nymph.
Emergence -- appearance of the first part of the crop plant through the ground.
Emulsifying agent -- a material that allows one liquid to be suspended in another.
Emulsion -- a mixture where a liquid is suspended in tiny droplets in another liquid such as oil in water.
Entomology -- the study of insects.
Environment -- the external conditions and influences surrounding living organisms.
Eradicant -- a chemical used to eliminate a pathogen from the host or environment.
Eriophyid -- tiny mites characterized by a slender body and two, not four pairs of legs.
Evapotranspiration -- total loss of moisture through the combined process of evaporation and transpiration
Exoskeleton -- hard or resistant outside covering of an insect.
Exudate -- material pushed from infected areas.

F

Facultative -- see obligate
Family -- a classification unit of genera with certain characteristics that make them related.
Flail mower -- a mower that cuts turf by high-speed impact of blades rotating in a vertical plane relative to the turf surface.
Floret -- a grass flower enclosed by a lemma and paella.
Flowable -- a finely ground wet-able powder formulation sold as a thick suspension in a liquid. Flowables require only moderate agitation and seldom clog spray nozzles.
Foliar burn -- injury to shoot tissue caused by dehydration because of contact with high concentrations of fertilizers and pesticides.
Foliar application -- application of a pesticide to the leaves of plants.
Formulation -- how a pesticide is offered for sale to the user (as emulsifiable concentrate, wet-able powder, granule, dust, oil solution, etc.). Includes active and inert ingredients.
Frass -- wood fragments mixed with excrement produced by an insect.
Fumigant -- a pesticide that kills destructive microorganisms, animals and plants as a gas.
Fungal -- relating to fungi.
Fungicide -- a pesticide that controls fungal infections.
Fungus -- (pl. Fungi) a plant organism that is not differentiated into root, stem and leaves and is devoid of chlorophyll.

G

Gall -- an unusual enlargement of a portion of a plant tissue stimulated by pest attack.
Genus -- (pl. Genera) a group of species with common characteristics.
Glumes -- a pair of bracts usually present at the base of a grass spikelet.
Granular -- dry pesticide formulation with particles less than ten cubic millimeters in size.
Grass -- any member of the family Gramineae (Poaceae).
Ground cover -- low-growing, broadleaf plant used to cover the soil.
Grub -- larvae of certain beetles and also some flies.

H

Habitat -- the environment in which an organism lives.
Hazard -- the likelihood of an injury from pesticide use. Hazards constitutes both toxicity and exposure.
Head -- the first division of the insect body.
Herbaceous -- soft, lacking woody tissue.
Herbicide -- a chemical that kills plants. Toxicity may vary with dosage, method of application, etc.
Honeydew -- sweet, sticky excretion of aphids, leafhoppers scales, mealybugs, whiteflies.
Host -- organism that a parasite lives on.
Humus -- the organic fractions of soil in which decomposition is so far advanced that its original form cannot be distinguished.
HB-- product of a cross between individuals of unlike genetic compositions.
Hydroseed -- applying seed and water with fertilizer and mulch by spraying.
Hyperplasia -- abnormal tissue development by an increase in cell numbers.
Hypertrophy -- abnormal tissue development by an increase in the size of individual cells.
Hypha -- (pl. Hyphae) -filaments which collectively form the mycelium of a fungus.
Hypoplasia -- underdevelopment of growth or multiplication.

I

Incomplete metamorphosis -- life cycle of three stages of egg, nymph and adult, example: Grasshoppers.
Incubation period -- the time from introduction of inoculum to the host and when the disease becomes microscopically evident.
Inert ingredients -- pesticide formulation ingredients that are not active, such as water, adjuvants, emulsifiers, propellants, etc.

Infectious disease -- a pathogen caused disease that can be transmitted between plants.
Infection -- the process of gaining entrance and establishing as a parasite.
Infection site -- the area on a plant where a pathogen gains entrance to the host.
Infest -- to overrun.
Inflorescence -- flowers and supporting systems.
Inoculation -- the process of transferring inoculum to a host.
Inoculum -- the part of a pathogen that is transferred to a host. It consists of spores, bacteria, or mycelial fragments.
Insecta -- a class in the phylum arthropoda.
Insecticide -- a pesticide used to prevent, destroy, repel, mitigate or attract insects.
Instar -- insect stages between molts.
Integrated pest management (IPM) -- controlling pest populations through chemical, physical, cultural, biological and regulatory methods.
Internode -- portion of a stem between the nodes of growing points.

L

Label -- a printed statement affixed to the pesticide container by the manufacturer, listing the contents, directions for use, and precautions. These must be approved and registered by the U S Environmental Protection Agency and the Utah Department of Agriculture and Food.
Larva -- (pl. Larvae) the immature or worm stage (caterpillar, maggot, grub) of an insect that passes through four stages (egg, larva, pupae, adult) in its development.
Lateral shoot -- a shoot originating from a vegetative bud in the axil of a leaf or from the node of a stem, rhizome or stolon.
Leaching -- washing soluble materials from the soil by the downward movement of water.
Leaflet -- secondary division of the compound leaf.
Leathery wing -- thickened, flexible front wings of grasshoppers and earwigs.
Lesion -- a localized area of sunken or discolored diseased tissue.
Life cycle -- the changes between birth and death of the organism.
Ligule -- a membranous or hair-like appendage inside the grass leafs at the junction of the leaf and blade.
Local invasion -- involving localized area of the plant. –
See systemic invasion.
Localized dry spot -- a dry spot amid normal, moist turf that resists rewetting. May be associated with thatch, fungal activity, shallow soils, or elevated sites in the terrain.

M

Maggot -- larvae of the higher diptera, especially families related to houseflies.
Melting out -- a fungal disease that shows as dark leaf spots, often followed by dieback of irregular areas of turf.
Microorganism -- tiny living organism such as bacteria, fungi, nematode or virus.
Midrib -- the central vein of a grass leaf, extending from the stem to the leaf tip.
Mold -- any fungus with conspicuous mycelium or spore masses. Often saprophytic they grow on damp decaying matter or plants.
Mottle -- an irregular pattern of light and dark areas.
Mouth parts -- the name given to all parts of the mouth collectively.
Mowing pattern -- travel pattern while mowing turf. Patterns are changed to distribute wear and compaction, to avoid creating "grain," and create visually aesthetic effects for sports.
Mowing height -- the height above the ground that the turf grass is cut during mowing.
Mowing frequency -- the number of times turf is mowed per week or other interval.
Mowing interval -- the time period between successive mowing.
Mulch -- any material (straw, sawdust, leaves, plastic film, etc.) spread on the soil.
Mummy -- a dried, diseased fruit.
Mycelium -- collective term for a masses of hyphae or fungus filaments.

N

Necrosis -- a pathological condition marked by rapid destruction of cell structures and consequent tissue death.
Necrosis (adj. Necrotic) **--** death, usually accompanied by darkening or discoloration.
Nematicide -- a pesticide used to prevent, repel, destroy or mitigate nematodes.
Nematodes -- generally microscopic, unsegmented roundworms that usually live free in moist soil, water, or decaying matter, or as parasites of plants and animals.
Nitrification -- formation of nitrates and nitrites from ammonia by soil microorganisms.
Nocturnal -- active at night.
Node -- the joint of a stem or the region of attachment of leaves on a stem.
Nonselective herbicide -- a chemical that is toxic to plants regardless of species. Toxicity varies with dosage, application, etc.
Noninfectious disease -- a disease caused by unfavorable growing conditions that cannot be transmitted from plant to plant.

Nozzle -- a device for metering and dispersing a spray solution.
Nymph -- the immature stage (resembling an adult) of an insect that passes through three stages (egg, nymph and adult) of development.

O

Obligate parasite --organisms that can live only as parasites.
Obligate -- necessary, essential parasite, surviving on living tissue.
Obligate saprophyte -- organisms that can live only as saprophytes.
Opposite -- leaves attached precisely opposite each other on a stem.
Organic matter -- plant or animal materials that can be broken down and re-synthesized in soil.
Organophosphate insecticide -- a compound synthesized from phosphoric acid. These are primarily contact killers with short-lived effects. Examples are malathion, diazinon, trichlorfon, and dimethoate.
Orifice -- an opening in a nozzle tip through which the spray, dust or granules flow.
Overseed -- seeding in existing turf, usually with temporary turf grass, to provide green, active grass growth during dormancy of the original turf (usually a warm-season turf grass).
Ovipositor -- a tubular structure on female insects for depositing of eggs.

P

Palmate -- three or more lobes, leaflets or veins arising from one point.
Panicle -- inflorescence type where spikelets are not directly attached to the main axis.
Parasite -- a fungus, bacterium, virus, nematode, etc. That obtains food from other organisms. Obligate parasites only develop in living tissues (e.g., a virus or parasitic nematode).
Parasitic insect -- an insect that lives in or on the body of another insect.
Particle drift -- spray particles carried from the application area by air movements.
Pathogen -- disease producing organism.
Pathogenicity -- ability of an organism to produce disease.
Pathology -- the study of disease.
Pellet -- a dry pesticide formulation of particles larger than ten cubic millimeters.
Perennial -- a plant that lives for three years or more under normal growing conditions.
Persistent herbicide -- a herbicide, that applied at the recommended rate, harms susceptible crops planted after harvesting the treated crop, or which interferes with plant re-growth for an extended period of time.
Pesticide -- a material that will kill, reduce, ease the effects of, or control weeds, diseases, insects, rodents and other pests.
Petal -- flower parts surrounding the stamen and pistil that is sometimes colorful or showy.
Petiole -- the stalk of a leaf.
Ph soil -- a numerical measure of soil acidity or hydrogen ion activity. A ph of 7 is neutral, above 7 is basic or alkaline; below 7 is acidic.
Pheromone -- a biochemical substance produced by insects to attract others of the same species through the sense of smell.
Phloem -- the food conducting tissue of vascular plants.
Photosynthesis -- process of carbohydrate production from carbon dioxide, water, and light in chlorophyll containing plants.
Physiology -- the study of processes, activities and phenomena related to life.
Phytotoxic -- a pesticide that is injurious or poisonous to plants.
Phytotoxicity -- poisonous to plants
Piercing-sucking mouthparts -- mouthparts adapted for penetrating and sucking juices from tissues.
Pinnate --branches, lobes, leaflets or veins attached or arranged on two sides of a stem.
Pistil -- female flower structures consisting of an ovary and one or more stigmas and styles.
Plant-growth regulator -- a substance used for controlling or modifying plant-growth processes without appreciable phytotoxic effect at the dosage applied.
Post-emergence treatment -- treatment made after the crop plants emerge.
Post-emergent herbicide --herbicide applied after emergence of the crop or weed.
Posterior -- hind part.
Pre-emergent herbicide -- herbicide applied before emergence of a crop or weed.
Pre-plant herbicide -- a herbicide that is applied before the crop is planted.
Predator -- animals that devour others.
Predatory or predaceous insect -- an insect that feeds on other insects.
Prolegs -- fleshy abdominal legs of certain insect larvae.
Protectant -- a pesticide used to prevent infection by an organism.
PSI -- pressure measured in pounds per square inch.
Pupa (pl. Pupae) -- the resting state of an insect that passes through four stages (egg, larvae, pupa and adult) in its development.
Pupate -- to change from the larval stage to the pupal stage.

Pure live seed (PLS) -- percentage of the content of a seed lot that is pure and viable.
Pustule -- a pimple-like or blister-like area on leaves or bark concealing the causal agents such as rust or smut.

R

Raceme -- type of inflorescence in which the spikelets are borne on short stems with pedicels attached directly to the main axis.
Rasping -- sucking mouth parts with structures for roughening plant tissues, and modification of structures for sucking juices.
Rate and dosage -- these terms are synonymous. “Rate” is the preferred term. The amount of active ingredient (such as 2,4-D acid equivalent) applied to an area (such as one acre), regardless of chemical percentage in the carrier.
Re-establishment -- rebuilding a lawn by complete removal of any existing turf, followed by site preparation and planting.
Recuperative potential -- the ability of a turf grass to recover from injury through vegetative growth.
Renovation, turf -- turf improvement by planting in existing live and/or dead vegetation.
Residual -- the ability of a pesticide to persist after application in amounts that will kill pests for several days to several weeks or longer.
Residue -- the amount of pesticide present following application.
Resistant species -- pests that survive relatively high rates of pesticide application.
Resting spore -- a thick-walled, spore that may remain alive in a dormant state for months or years, later germinating and being capable of causing infection.
Rhizome -- underground stem capable of sending out roots and leafy shoots.
Rogue -- remove; pull out.
Root zone -- the upper six to eight inches of soil, where most turf-grass roots are concentrated.
Rosette -- a basal, circular cluster of leaves not separated by evident internodal-stem elongation.
Runoff -- pesticide material that is carried away from an area by the flow of surface water. Also used to describe the rate of application to a surface -- “spray to runoff.”
Rust -- a fungus with orange spores or the disease caused those fungi.

S

Salinity -- excessive soluble salts in the soil.
Saprophyte -- an organism that obtains its food from dead organic matter, as opposed to a parasite that feeds on living tissue. See parasite.
Scald --turf collapse and browning because shallow, standing water gets too hot.
Scale insects -- insects that characterized by hard, convex coverings over their body with no visible appendages or segmentation. .
Scalp -- to remove excessive amounts of functioning green leaves with mowing. Gives a shabby, brown appearance from exposing crowns, stolons, dead leaves, and even bare soil.
Sclerotium -- (pl. Sclerotia) a compact, dense mass of mycelia serving as a resting body.
Scum -- algae layer on the soil surface of thinned turfs.
Drying produces an impervious layer that impairs subsequent shoot emergence.
Secondary infections -- infections initiated, usually during the summer, by inocula from primary or other secondary infections without a dormant period.
Sedge -- a grass-like plant with triangular stems that spreads by rhizomes..
Seed blend -- a combination of seeds of two or more cultivars of the same turf-grass species.
Seedhead -- floral development; in the case of grasses, usually a fruiting cluster or spike.
Selective herbicide -- a chemical that is more toxic to some plant species than to others.
Selectivity -- the ability of a pesticide to kill some pests but not others.
Sheath -- the tubular, basal portion of the leaf that encloses the stem.
Shoot Density-- the relative number of shoots per unit area.
Sign -- the structure of the pathogen itself.
Skeletonize -- to remove the green portions of a leaf, leaving veins, midribs or transparent membranes.
Slicing -- a method of turf cultivation in which rotating flat tines slice intermittently through the turf and the soil.
Slime mold -- primitive organisms whose plasmodium "flows" over low-lying vegetation like an amoeba.
Slit Trench drain -- a narrow trench backfilled to the surface with a porous material such as sand, gravel, or crushed rock. Used to intercept surface or lateral subsurface drainage water.
Slow release fertilizer -- fertilizers that are not totally water soluble. Compounds may dissolve slowly, be decomposed by microbes or be coated with impermeable materials. Used interchangeably with controlled release or availability and slow acting.
Slug-like -- larvae of sawflies and of some moths which resemble slugs.
Snout beetle -- a weevil with a long snout with chewing mouthparts.

Sod -- plugs, squares or strips of turf grass, with adhering soil used in vegetative planting.
Soil application -- a herbicide applied to the soil surface rather than to vegetation.
Soil modification -- alteration of soil characteristics by adding soil amendments; commonly used to improve physical conditions.
Soil probe -- a cylindrical soil-sampling tool with a cutting edge at the lower end.
Soil sterilant -- pesticide that renders soil incapable of supporting plants. Sterilization may be temporary or almost permanent.
Soil sterilization -- treating soil by heat or chemicals to kill living organisms.
Solubility -- the ability of a liquid or solid to dissolve in liquid.
Soluble powder -- a powder formulation that dissolves and forms a solution in water.
Solution -- a pesticide dissolved in a liquid. The pesticide is evenly dispersed as individual molecules among the molecules of liquid.
Sooty mold -- a dark, often black, fungus growing on insect honeydew.
Species --taxonomic classification, below the genus of related organisms capable of interbreeding
Spiking -- a method of turf cultivation in which solid tines or flat, pointed blades penetrate the turf and soil surface. **Spiracle --** the external opening of the respiratory organ of "air-breathing" insects.
Spoon, coring -- turf cultivation using curved, hollow, spoon-like tines to remove soil cores and leave a hole or cavity in the sod.
Spore -- microscopic one- to many-celled tissue that may break free, germinate, and produce a new organism. In fungi, one-celled structures formed by mycelium
Spot treatment -- pesticide treatment applied to a small area of a larger unit. Example; treatment of weed patches within a larger field.
Spray deposit -- the pesticide that hits the plant or other surface.
Spray drift -- the movement of airborne particles beyond the intended contact area.
Spreader -- material added to a spray preparation to improve contact between the chemical and the plant surface.
Sprig -- grass stem (stolon, rhizome or tiller), with attached roots for vegetative propagation.
Sprigging -- vegetative planting of stolons, rhizomes or tillers.
Stand -- the number of established individual shoots per unit area.
Stemmother -- in aphids, those hatching from over-wintered eggs and producing summer generations that reproduce without fertilization.
Stolon -- an elongated horizontal stem (or shoot) that grows above the soil and roots at the nodes. It is used to propagate certain grasses.
Stoma (pl. Stomata) **--** a tiny opening in the epidermis of a leaf or stem through which gases are exchanged.
Stool -- to throw out shoots; to tiller.
Stomach poison -- a poison which kills the insect when it eats the food.
Stomata -- (pl.stoma) small openings or pores on leaves or stems.
Streak -- necrosis along vascular bundles in leaves or stems of grasses.
Subgrade -- the surface grade of a turf site before the addition of topsoil.
Surfactant -- adjuvants that reduce surface tension between two unlike materials, such as oil and water. A spreader or wetting agent used to increase coverage of the surface being sprayed.
Susceptible species -- pests readily killed by relatively low rates of pesticide application.
Suspension -- a mixture of tiny pesticide particles in a solid form, suspended in water.
Symptom -- the reaction of a plant or animal to a pest's activities indicating diseased condition.
Synergism -- the action that produces a greater cumulative effect when two pesticides are used together than when used individually.
Syringe -- spraying turf with water on hot, dry days, to reduce water loss (transpiration).
Systemic chemicals -- chemicals that enter plants and move from point of contact.
Systemic pesticide -- a pesticide absorbed by treated plants and translocated (moved) to other tissues.
Systemic invasion -- microorganisms that enter and move throughout the plant.

T

Taproot -- a single, large, primary root..
Taxonomist -- a person trained in the classification of plants or animals.
Thatch -- a tightly intermingled layer of organic residue between the base of the grass and the soil.
Thatch control -- preventing excessive thatch accumulation by cultural manipulation and/or reducing excess thatch by mechanical or biological methods.
Thorax -- the middle region of an insect's body, where the legs and wings are attached.
Tiller -- a lateral stem or shoot that develops from the central crown.
Tolerance -- the ability of an organism to tolerate a pesticide.
Topdressing -- applying a prepared soil mix to the turf surface..

Total vegetation control -- herbicide applications providing pre-emergence and/or post-emergence control of all plants. The term usually refers to non-crop areas.
Toxicity -- the ability of a pesticide to harm a living organism.
Transitional climatic zone -- the zone between temperate and subtropical climates.
Translocated herbicide -- a herbicide moved within the plant.
Transmission -- spread of pathogens from plant to plant.
Tuber -- a swollen underground stem with numerous buds.
Tumor -- abnormal swelling or growth.
Turfgrass community -- grass plants that relate to the environment and other individual plants.

U

Urea formaldehyde -- slowly soluble nitrogen fertilizer of methylene-urea polymers; formed by reacting urea and formaldehyde.

V

Vapor drift -- the movement of chemicals after they change to a gas. Some pesticides change into vapors that drift and damage susceptible plants near the application site.
Variety -- a subspecies or a near relative with minor differentiations.
Vascular -- xylem and phloem conductive tissue.
Vector -- agent that transmits pathogens.
Vegetative propagation -- asexual propagation using any plant part except the seed.
Veination -- vein arrangement of a leaf.
Vertical mower -- a mechanical device with vertically rotating blades that cut into turf to remove matted top growth.
Virulent -- highly pathogenic.
Virus -- submicroscopic parasite that cause mosaics, ring-spots, and other plant diseases. Viruses only reproduce in living cells.
Volatilize--vaporize or change from a liquid to a gas at certain temperatures.

W

Warm-season grass -- grass species that grow best at 80 to 95 degrees f..
Water-soaked -- lesions that appear wet, dark, and usually sunken and translucent.
Weed -- any plant growing where it is not wanted.
Weevil -- small snout beetles in the suborder Rhynchophora.
Wet-able powder -- a dry formulation containing a wetting agent that helps the powder form a suspension in water.
Wetting agent -- a compound added to sprays helping it thoroughly wet plant surfaces.
Wilt -- limpness of plant parts caused by insufficient water in the plant.
Wind burn -- death and browning of leaves caused by desiccation.
Wing membrane -- the membranous portion of the wings between the veins.
Winter annual -- a plant that starts growing in the fall, lives over winter, and produces seed the following spring.
Winter desiccation -- plant tissue death by drying, during winter dormancy.
Winter over-seeding -- seeding cool season grass over warm season grass in transition climates to give green turf during the winter, when warm season grass goes dormant.
Winterkill -- plant injury that occurs during the winter period.
Witches' broom -- an abnormal cluster of twigs or a brush-like growth on woody plants.

X

Xylem -- water-conducting tissue in plants.

Z

Zonate -- target-like or appearing in concentric rings

CALIBRATION INFORMATION

Unit Conversion

One acre = 43,560 square feet	**Example: ½ acre = 21,780 square feet**
One mile = 5,280 feet	Example: ¼ mile = 1320 feet
One gallon = 128 fluid ounces	Example: ½ gallon = 64 fluid ounces
One quart = 2 pints = 4 cups = 32 fluid ounces	Example: 2 quarts = 64 fluid ounces
One pint = 2 cups = 16 fluid ounces	Example: ½ pint = 1 cup = 8 fluid ounces
One tablespoon = 3 teaspoons = 0.5 fluid ounces	Example: 2 tablespoons = 1 fluid ounce
One pound = 16 ounces	Example: ¼ pound = 4 ounces
One gallon = 231 cubic inches	Example: 2 gallons = 462 cubic inches

Weights

1 ounce	= 28.35 grams
16 ounces	= 1 pound = 453.59 grams
1 gallon water	= 8.34 pounds = 3.785 liters = 3.78 kilograms

Liquid Measures

1 fluid ounce	= 2 tablespoons = 29.573 milliliters
16 fluid ounces	= 1 pint = 0.473 liters
2 pints	= 1 quart = 0.946 liters
8 pints	= 4 quarts = 1 gallon = 3.785 liters

Length

1 foot	= 30.48 centimeters
3 feet	= 1 yard = 0.9144 meters
16 1/2 feet	= 1 rod = 5.029 meters
5280 feet	= 320 rods = 1 mile = 1.6 kilometers

Area

1 square foot	= 929.03 square centimeters
9 square feet	= 1 square yard = 0.836 square meters
43560 square feet	= 160 square rods = 1 acre = 0.405 hectares

Speed

1.466 feet per second	= 88 feet per minute = 1 mph = 1.6 kilometers per hour (kph)

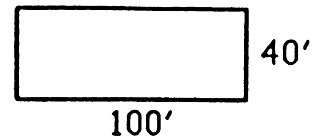
Volume

27 cubic feet = 1 cubic yard = 0.765 cubic meters 1 cubic foot = 7.5 gallons = 28.317 cubic decimeters

Area and Volume Calculations:

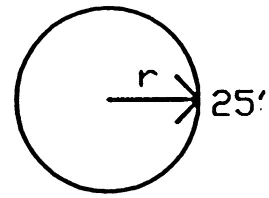
Area of Rectangular or Square Shape

The area of a rectangle is found by multiplying the length (L) times the width (W).
(Length) x (Width) = Area
Example: (100 feet) x (40 feet) = 4000 square feet



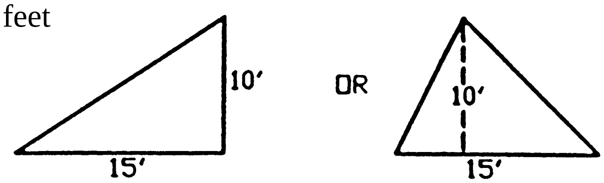
Area of Circle

The area of a circle is the radius (radius = one-half the diameter), times the radius, times 3.14.
(radius) x (radius) x (3.14) = Area
Example: (25 feet) x (25 feet) x (3.14) = 1962.5 square feet



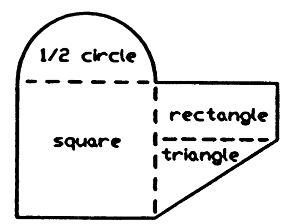
Area of Triangular Shape

To find the area of a triangle, multiply ½ times the width of the triangle's base, times the height of the triangle.
(½) x (base width) x (height) = Area
Example: (½) x (15 feet) x (10 feet) = 75 square feet

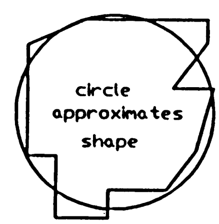


Area of Irregularly Shape

Irregularly shaped sites can often be reduced to a combination of rectangles, circles, and triangles. Calculate the area of each shape and add the values together to obtain the total area.
Example: Calculate the area of the rectangle, triangle,
square, and one-half of a circle.



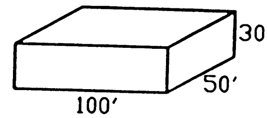
Another method is to convert the site into a circle. From a center point, measure the distance to the edge of the area in 10 or more increments. Average these measurements to find the radius, then calculate the area using the formula for a circle.
Example: Approximate the area by calculating
the area of a similarly sized circle.



Volume of Cube and Box Shapes

The volume of a cube or box is found by multiplying the length, times the width, times the height.
(Length) x (Width) x (Height) = Volume

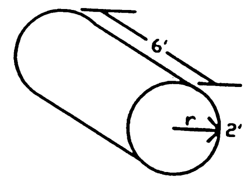
Example: (100 feet) x (50 feet) x (30 feet) = 150,000 cubic feet



Volume of Cylindrical Shapes

The volume of a cylinder is found by calculating the area of the round end (see formula for circle) and multiplying this area times the length or height.

Example: (radius) x (radius) x (3.14) = Area of Circle
(Area of Circle) x (Length) = Volume of Cylinder
(2 feet) x (2 feet) x (3.14) x (6 feet) = 75.36 cubic feet



Sprayer Calibration Formulas

To Calculate Travel Speed in Miles Per Hour:
The travel speed of a sprayer is determined by measuring the time (seconds) required to travel a know distance (such as 200 feet). Insert the values in the following formula to determine the miles per hour.

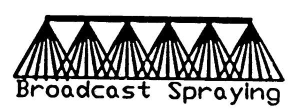
$$\frac{\text{Distance in Feet x 60}}{\text{Time in Seconds x 88}} = \text{Miles Per Hour}$$

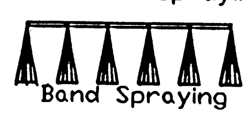
Example: $\frac{\text{(200 feet) x (60)}}{\text{(30 seconds) x (88)}} = \frac{12{,}000}{2640} = 4.55$ mph

To Calculate the Gallons Per Minute Applied During Broadcast Spraying:
The application rate in gallons per minute (GPM) for each nozzle is calculated by multiplying the gallons per acre (GPA), times the miles per hour (MPH), times the nozzle spacing in inches (W); then dividing the answer by 5940. For small adjustments in GPM sprayed, operating pressure is changed. For large adjustments in GPM sprayed, travel speed (miles per hour) is changed or nozzle size is changed.

$$\frac{\text{GPA x MPH x W}}{5940} = \text{GPM}$$

Example: $\frac{\text{(12 GPA) x (4.5 MPH) x (24”)}}{5940} = \frac{1296}{5940} = 0.22$ GPM





To Calculate the Gallons Per Minute Applied During Band Spraying:
Broadcast spraying applies chemicals to the entire area. Band spraying reduces the amount of area and chemicals sprayed per acre. To use the above formulas for band sprayer applications, use the band width (measured in inches) rather than nozzle spacing for the “W” value.

Pesticide Mixing

Terminology:

The ***active ingredients*** of a pesticide are the chemicals in a formulation that control the target pests. The ***formulation*** is the pesticide product as sold, usually a mixture of concentrated active ingredients and an inert material. Restricted use pesticides are purchased in formulations requiring ***dilution prior to application***. Formulations are diluted with inert substances such as water. The ***percentage of active ingredients*** in a pesticide formulation directly affects dilution and application rates. Given two pesticides, A = 50% active ingredients, B = 100% active ingredients; twice as much pesticide A formulation is required to equal pesticide B formulation.

To Determine Total Amount of Pesticide Formulation Required Per Tank:

To calculate the total amount of pesticide formulation needed per spray tank, multiply the recommended dilution, ounces/pints/cups/teaspoons/tablespoons/etc. of pesticide per gallon of liquid, times the total number of gallons to be mixed in the sprayer. A full or partial tank of pesticide spray may be mixed.

(Dilution Per Gallon) x (Number of Gallons Mixed) = Required Amount of Pesticide Formulation

Example: (3 ounces per gallon) x (75 gallons) = 225 ounces

Note: 1 gallon = 128 ounces; through unit conversion 225 ounces = 1.76 gallons

To Calculate the Amount of Pesticide Formulation Sprayed Per Acre:

The amount of pesticide formulation sprayed per acre is determined by multiplying the quantity of formulation (ounces/pounds/pints/cups/teaspoons/tablespoons/etc.) mixed per gallon of water, times the number of gallons sprayed per acre.

(Quantity of Formulation Per Gallon) x (Gallons Sprayed Per Acre) = Formulation Sprayed Per Acre

Example: (1/2 pound per gallon) x (12 gallons per acre) = 6 pounds per acre

Amount of Active Ingredients Sprayed Per Acre:

To calculate the amount of active ingredients (AI) applied per acre, multiply the amount (pounds, gallons, ounces, etc) of pesticide formulation required per acre, times the percentage of active ingredients in the formulation (100%, 75%, 50%, 25%, etc.), and divide the value by 100.

$$\frac{\text{(Amount of Formulation Required Per Acre) x (Percentage of AI)}}{100} = \text{Active Ingredients Per Acre}$$

Example: $$\frac{\text{(4 pounds formulation sprayed per acre) x (75\% AI)}}{100} = \text{3 pounds of AI sprayed per acre}$$

Note: 75 % = 0.75

To Calculate the Gallons of Pesticide Mixture Sprayed Per Acre:

The amount of pesticide mixture sprayed per acre is determined by dividing the number of gallons sprayed by the number of acres sprayed.

$$\frac{\text{Gallons Sprayed}}{\text{Acres Sprayed}} = \text{Gallons Sprayed Per Acre}$$

Example: $$\frac{\text{200 Gallons Sprayed}}{\text{10 Acres Sprayed}} = \text{20 gallons of pesticide mixture sprayed per acre}$$